INFLUENCE OF IDEALIZED PUSHOVER CURVES
ON
SEISMIC RESPONSE

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ABSTRACT

INFLUENCE OF IDEALIZED PUSHOVER CURVES ON SEISMIC RESPONSE

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Contemporary approach performance based engineering generally relies on the approximate procedures that are based on the use of capacity curve derived from pushover analysis. The most important parameter in the displacement-based approach is the inelastic displacement demand computed under a given seismic effect and the most common procedures employed for this estimation; the Capacity Spectrum Method and the Displacement Coefficient Method are based on bi-linearization of the capacity curve. Although there are some recommendations for this approximation, there is a vital need for rational guidelines towards the selection of the most appropriate method among several alternatives.

Considering the presence of several idealization alternatives and the absence of rational guidelines to select the most suitable method, a comprehensive research has been undertaken to evaluate the influence of several existing alternatives used for approximating the capacity curve on seismic demands. A number of frames were analyzed under a set of 100 ground motions employing OpenSees as the structural analysis platform. In addition to the nonlinear time history analyses conducted on multi-degree-of-freedom frame systems, nonlinear static analyses were also utilized to obtain the global response of the frames. The pushover curves obtained were later approximated using several alternatives and the resulting curves were assigned as the force-deformation relationships of corresponding equivalent single-degree-of-freedom systems. These simplified systems were analyzed under the same ground motion database to evaluate the errors in predicting the seismic responses in terms of displacement, story drift and force demands.

Using the results of the complex and simplified analyses, the performance of each approximation method was evaluated in estimating the 'exact' inelastic deformations of the multi-degree-of-freedom systems at various degrees of inelasticity. Dependency of the errors on ductility, strength reduction factor and period was also investigated for different alternatives of idealization of the capacity curve. Moreover, the results of common bi-linearization methods were also compared with the results obtained from the analyses of multi-linearized capacity curve in order to seek the performance of these methods in predicting global response. The interpretations made and the conclusions drawn in this study is believed to clarify the rationality and accuracy of selecting the appropriate idealization of the capacity curve.

Keywords: Pushover analysis, approximate procedures, bi-linearization, capacity curve

ÖZ

BASİTLEŞTİRİLMİŞ PUSHOVER EĞRİLERİNİN SİSMİK DAVRANIŞ ÜZERİNDEKİ ETKİSİ

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Günümüz yaklaşımı olan performansa dayalı mühendislik genel olarak, binaların itme analizinden elde edilmiş kapasite eğrilerinin kullanımına dayalı yaklaşık yöntemler üzerine kurulmuştur. Deplasmana dayalı yaklaşımdaki en önemli parametre belirli bir sismik etki altında hesaplanmış olan elastik olmayan deplasman talebidir ve bu parametrenin tahmini için sıkça kullanılan yöntemlerden Kapasite Spektrum ve Deplasman Katsayısı metotları itme eğrilerinin basitleştirilmiş haline dayanır. Kapasite eğrilerinin basitleştirilmesi için çeşitli öneriler bulunmasına rağmen, bu önerilerden en uygun olanının seçilmesine yönelik rasyonel yönergelere ihtiyaç duyulmaktadır.

Birçok idealleştirme alternatifinin bulunması ve en uygun metodun seçilebilmesi için gereken yönergelerin eksikliği göz önünde bulundurularak, itme eğrilerinin idealleştirmesinde kullanılan mevcut alternatiflerin sismik davranış üzerindeki etkisini incelemek üzere detaylı bir araştırma yapılmıştır. Bu amaçla, OpenSees analiz platformu kullanılarak 7 çerçeve 100 ayrı deprem altında analiz edilmiştir. Çerçevelerin çok serbestlik dereceli modelleri üzerinde yapılan elastik ötesi dinamik analizlere ek olarak, çerçevelerin genel davranışını elde edebilmek amacıyla lineer olmayan statik analizler de yapılmıştır. Elde edilen pushover eğrileri çeşitli alternatifler kullanılarak idealleştirilmiş ve eşdeğer tek serbestlik dereceli sistemlerin kuvvet-deplasman ilişkisi olarak atanmıştır. Basitleştirilmiş bu modeller aynı deprem veritabanı kullanılarak analiz edilmiş ve deplasman, kat ötelenmesi ve kuvvet bazlı sismik davranış parametreleri yaklaşık olarak da hesaplanmıştır.

Kapsamlı ve basitleştirilmiş analizlerden elde edilmiş sonuçlar, idealleştirme alternatiflerinin çok serbestlik dereceli sistemin çeşitli elastik ötesi seviyelerindeki performansının değerlendirilmesinde kullanılmıştır. Ayrıca, alternatiflerin hata oranlarının süneklik seviyesi, kuvvet azaltım seviyesi ve periyoda bağlı değişimleri de rasyonel olarak irdelenmiştir. Bununla birlikte, sık olarak kullanılan idealleştirme alternatiflerinin kapasite eğrisinin orijinal haline göre de değerlendirmesi yapılmış olup, bu metotların genel davranışı ne kadar iyi yakalayabildikleri de incelenmiştir. Bu çalışmada; elde edilen sonuçlar ve yapılan yorumlar sayesinde en uygun basitleştirme yönteminin rasyonel olarak seçilmesine yönelik bilimsel bir katkı sağlandığı düşünülmektedir.

Anahtar Sözcükler: İtme analizi, yaklaşık yöntemler, basitleştirme, kapasite eğrisi

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Contemporary approach, named as performance based engineering, generally utilizes approximate procedures rather than conducting nonlinear time history analyses either to evaluate existing structures or to design new ones. The reason behind employing approximate procedures is simply the presence of many drawbacks of nonlinear time history analysis. Since the nonlinear time history analysis method is computationally complex, structural engineering community does not prefer it for analyzing the structures most of the time. In contrast to nonlinear time history analysis method, the simplicity provided considering both modeling and computational scheme in nonlinear static analysis and the easiness of its use and interpretability, although at the expense of accuracy, have made this analysis method the an attractive alternative.

The nonlinear static analysis, or shortly the pushover analysis, reflects the global behavior of a structure through a capacity curve representing the lateral force-deformation characteristics of the structure and forms the basis of approximate procedures which use the capacity curve to determine the seismic demands imposed on the structure. The most important parameter among the engineering demand parameters in performance based evaluation and design is the inelastic displacement demand under a given seismic event. To determine the inelastic deformation demand, two widely used approximate procedures that rely on pushover curve of the structure exist. These procedures, namely the Capacity Spectrum Method of ATC-40 [3] and the Displacement Coefficient Method of FEMA 356 [10] generally use a bi-linear representation of the original pushover curve to compute the approximate inelastic displacement demand. The original pushover curve is typically obtained by applying a load pattern that represents the first mode response of the structure.

In these procedures, the multi-degree-of-freedom (MDOF) system is represented by an equivalent single-degree-of-freedom (SDOF) system with the idealized load-deformation curve. Then, the equivalent SDOF system is analyzed to obtain the approximate displacement demand. Further steps of performance assessment of the structure's components depend on this approximate displacement demand. Thus, the idealization of the capacity curve can be an important source of error that can affect the estimation of the inelastic displacement demand. Although there are some recommendations for this approximation, there is a crucial need for rational guidelines towards selection of the most appropriate method among several limited alternatives.

1.2 LITERATURE SURVEY

The idealization concept of force-deformation relationships was first used for the practical design computations of reinforced concrete elements in which the engineer was proportioning the members according to the ductility calculations in terms of displacement, rotation and curvature. Since ductility computation had to be based on realistic definition of yield deformation, several alternative definitions were used by previous investigators. As Park [16] expressed, alternative definitions of the yield displacement are 1) the displacement when longitudinal steel reinforcement yields, 2) the yield displacement of the equivalent elasto-plastic system with the same elastic stiffness and ultimate load as the real system, 3) the yield displacement of the equivalent elasto-plastic system with the same energy absorption as the real system, and 4) the yield displacement of the equivalent elasto-plastic system with reduced stiffness found as the secant stiffness at 75% of the ultimate lateral load H_u of the real system, as illustrated in Figure 1.1. The most realistic definition for the yield displacement for reinforced concrete structures was proposed as the last definition by Park [16]. The proposition was based on Priestley and Park [18] that aimed at improving the understanding of seismic performance of bridge substructures. As indicated in Priestley and Park [18], Park [16], and Paulay and Priestley [17], the last definition takes the secant stiffness as described in order to include the reduction in stiffness due to cracking near the end of the elastic range. The experiments conducted by Priestley and Park [18] supported the secant stiffness assumption such that under cyclic loading at high "elastic" response levels, the initial curved load-displacement characteristic would modify to a curve close to the linear relationship of the idealized response as depicted in Figure 1.2.

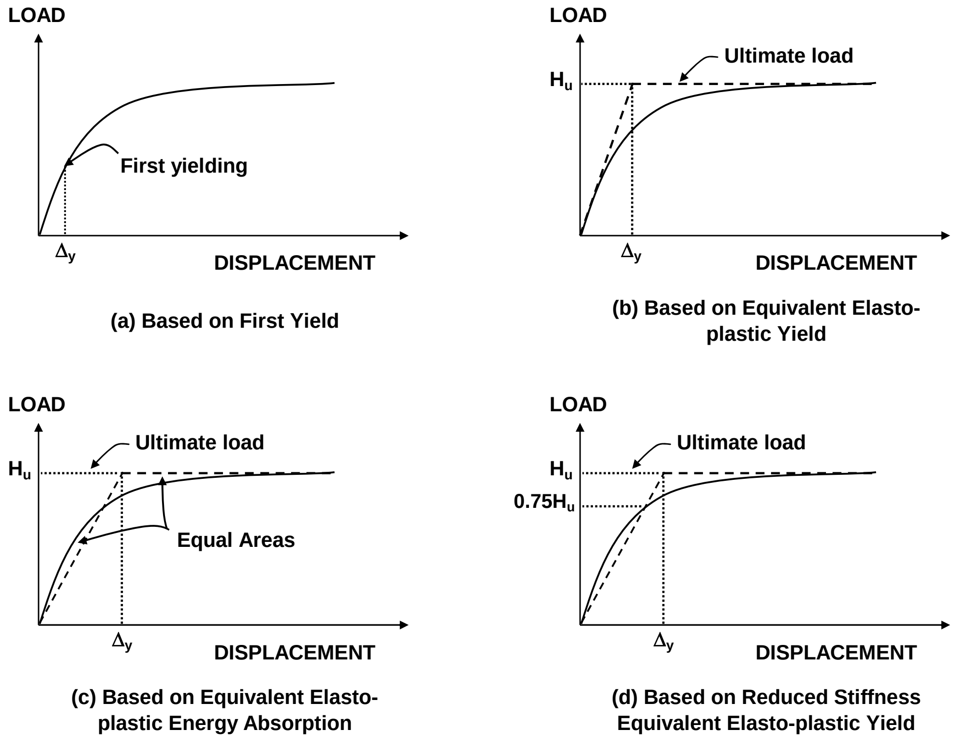

Figure 1.1 Alternative Definitions for Yield Displacement of Reinforced Concrete Elements (Park [16])

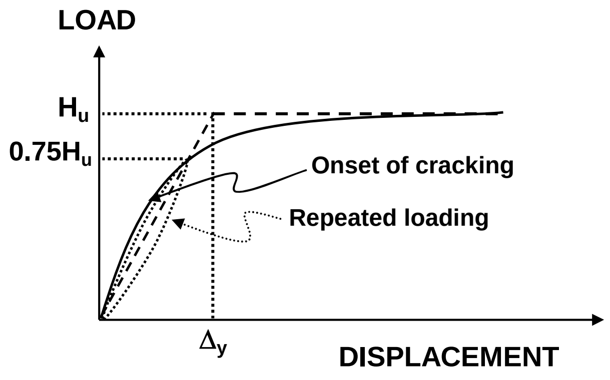

Figure 1.2 Typical Load-Displacement Relationship of a Reinforced Concrete Element (Paulay and Priestley [17])

Using the idea that the reinforced concrete frame systems are composed of reinforced concrete elements and the global structural behavior will be analogous to the component behavior, the first examples of idealizing force-displacement relationships of structures were based on the methods that are mentioned above. As it was recommended in ATC-19 [2], there were two common methods to idealize the force-deformation of a building for the purposes of design as illustrated in Figure 1.3.

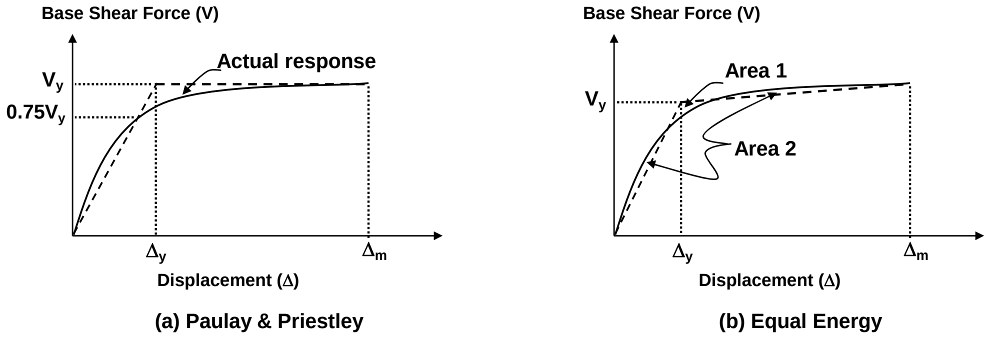

Figure 1.3 Bi-linearization Methods of a Force-Displacement Relationship (ATC-19 [2])

The first approximation, which was based on the method proposed by Paulay and Priestley [17] and had been developed for characterizing the load-displacement relation for reinforced concrete elements, assumes *a priori* knowledge of the yield strength (V_y) of the frame. The elastic stiffness is based on the secant stiffness of the frame calculated from the force-displacement curve at the force corresponding to $0.75V_y$.

The second method in the idealization of the load-deformation curve of a structure is commonly named as the equal-energy method. This method assumes that the area enclosed by the curve above the bi-linear approximation is equal to the area enclosed by the curve below the bi-linear approximation. According to ATC-19 [2], either of these methods could be used to estimate yield forces and yield displacements; these two methods would generally produce similar results for most ductile framing systems.

Later, in 1996, with the introduction of Capacity Spectrum Method (ATC-40 [3]) as a guideline for seismic evaluation, an initial stiffness based idealization method was recommended. In contrast with the previous methods, the idealization is held on the capacity spectrum of a structure which is used in conjunction with the Acceleration-Displacement-Response-Spectra (ADRS) to compute the performance point (target displacement) of the structure. According to ATC method, a bi-linear representation of the capacity spectrum is obtained by using the initial stiffness of the capacity curve and by satisfying the equal energy rule as shown in Figure 1.4. This bi-linear representation is later used for the estimation of the effective damping and appropriate reduction of spectral demand to determine the performance point of the building under an earthquake. A key point in this method is related with the trial performance point d_{pi}. Until determination of performance point, several trials are made with trial performance points. Thus, the bi-linearization of the capacity spectrum should be repeated for every trial to match the areas under each curve obtained.

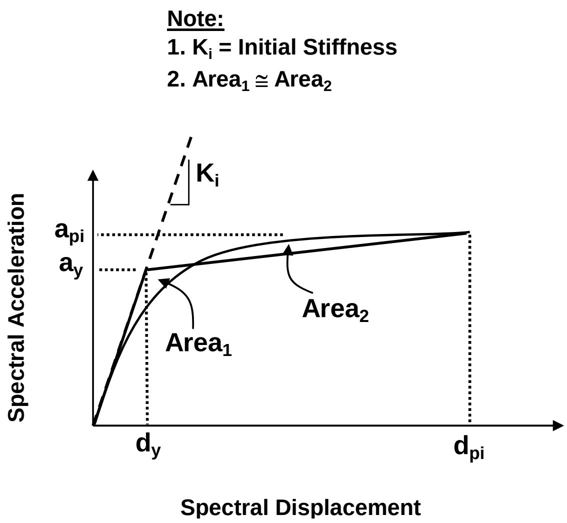

Figure 1.4 Bi-linear Representation of Capacity Spectrum
for Capacity Spectrum Method (ATC-40 [3])

Another common idealization method recommended by a rehabilitation guideline is the one presented in FEMA 273 [8] and FEMA 356 [10]. In accordance with the method that is used in Displacement Coefficient Method of FEMA, the nonlinear force-displacement relationship between the base shear and top displacement is replaced with an idealized relationship to calculate effective lateral stiffness, K_e, and effective yield strength, V_y, of the building as shown in Figure 1.5. Line segments on the idealized force-displacement curve are located using an iterative graphical procedure that approximately balances the area above and below the curve. The effective lateral stiffness, K_e, is taken as the secant stiffness calculated at a base shear force equal to 60% of the effective yield strength of the structure. The post-yield slope, α, is determined by a line segment that passes through the actual curve at the target displacement calculated. The effective yield strength is not taken as greater than the maximum base shear force at any point along the actual curve. In the commentary of FEMA (FEMA 274 [9]), the reason behind selecting 60% value to determine secant stiffness was the fact that the secant stiffness defined at this level would better represent the apparent fundamental period change with response amplitude, as a structure responds inelastically to an earthquake due to cracking. However, the rationality under this assumption was not described. It was also stated in the commentary that it would be more conservative to use a lower yield displacement and a lower secant stiffness.

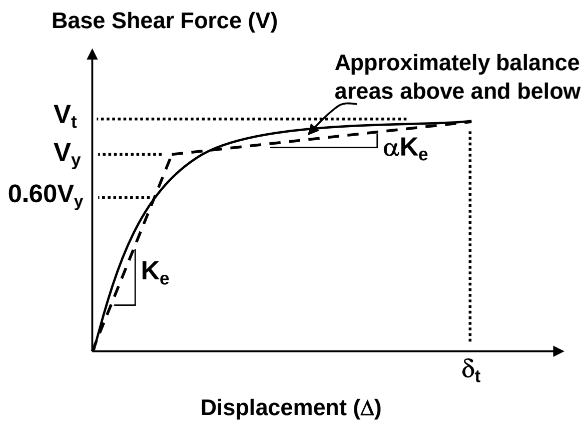

Figure 1.5 Idealized Force-Displacement Curve
for Displacement Coefficient Method (FEMA 356 [10])

As an improvement to the guidelines of ATC-40 [3] and FEMA 356 [10], FEMA 440 [4] was presented as the collection of large number of researchers who had devoted their studies on the accuracy of the approximate procedures by comparing the results with the nonlinear time history analyses and the document provided the latest improvements to both of these procedures. However, the rationality behind the idealizations and their consequential effects on seismic response were not presented again in this new guideline.

Apart from the common methods given in the guidelines mentioned, some attempts were also presented in the determination of the global yield displacement of either regular or irregular structural systems. Sullivan *et al.* [20], which is a specific example to those attempts, bases the idea of yielding on the yield of individual components that constitute the lateral resisting system. According to the proposition, the initial stiffness should be taken considering the initial stiffness of each wall weighted with proportion to the base shear it carries. Although this method could be applied to shear resisting systems, its use in moment resisting frames would be impractical. Additionally, the yield definition of an individual component is also a matter of discussion and makes it more complex. Thus, it would be better to utilize the common methods in sake of practical use for the engineers.

1.3 OBJECTIVE AND SCOPE

Considering the presence of several idealization alternatives and the absence of rational guidelines to select the most suitable method, a comprehensive research has been undertaken to evaluate the influence of several existing alternatives used for approximating the capacity curve on seismic demands.

In the context of this study, seven reinforced concrete frames were analyzed under nearly 100 ground motion records. Firstly, nonlinear time history analyses of the MDOF systems were conducted to compute the 'exact' seismic demands, namely maximum roof displacement, maximum inter-story drift ratio and maximum base shear. Secondly, nonlinear static analyses (pushover analyses) were utilized to estimate the load-deformation response of the structures. Using the elastic first mode lateral load pattern dependent capacity curves, the force-displacement relationships were idealized according to four methods in the further stages of the study. As the first method, which will be called as 'MULTI' from here on, the pushover curve was idealized using as many linear segments as needed to fully describe the whole curve. This idealization method was thought to be the best alternative to represent the nonlinear static response. The original curve was secondly idealized using the recommendations of ATC-40 [3] utilizing the initial stiffness definition and will be named as 'ATC' in the proceeding stages. As the third alternative, 'FEMA', the suggestions of FEMA 356 [10] were employed to bilinearize the capacity curve. Finally, the FEMA alternative was slightly modified to comply with the recommendations of Paulay and Priestley [17] and this method will be mentioned as ‘75%V_y’. In all alternatives, the requirement of the equal energy concept was satisfied.

Using the idealized capacity curves, MDOF systems were represented as equivalent SDOF systems and simplified systems were analyzed under the same ground motion database to compute the approximate displacement demands. In conjunction with the results of the nonlinear static analyses, the approximate values of other seismic demand parameters namely maximum inter-story drift ratio and maximum base shear were found.

As the next step of the study, results of approximate procedures in terms of roof displacement, inter-story drift ratio and base shear were compared with the ‘exact’ ones at various levels of global drift to investigate the effects of idealizations. Correlation studies were conducted to investigate the success of each method of idealization in estimating seismic demand parameters. In addition, trends and dependencies on ductility (μ), strength reduction factor (R) and period were examined. Along with the comparisons with respect to ‘exact’ values, the results of three common approximate procedures; ATC, FEMA and 75%V_y, were also compared with the results of MULTI method that was thought to fully describe the nonlinear static response of a structure.

In this study, it was aimed to provide rationality to the selection and the use of alternative methods of capacity curve idealization, by using the provided statistical results and the interpretations made over the dependencies and trends.

The thesis is composed of five main chapters and two appendices. Following the review of relevant idealization alternatives in this chapter, Chapter 2 presents the frames analyzed and the ground-motion database employed throughout the study. Chapter 3 contains the details of the nonlinear time history, nonlinear static and simplified dynamic analyses conducted. The modeling assumptions for the analysis methods are explained and the obtained results are presented. Moreover, a brief discussion is presented on how the results were compared at the end of the chapter. In Chapter 4, the interpretations of the analyses results are evaluated to investigate how the results obtained from approximate analyses correlate well with those obtained from ‘exact’ analyses. The dependencies and trends on ductility, strength reduction factor and period are also examined in the context of this chapter. Chapter 5 contains the summary, conclusions and further recommendations regarding the study. Appendix A includes the detailed descriptions of the frames, the results in terms of maximum roof displacement, maximum inter-story drift ratio and maximum base shear obtained from nonlinear time history analyses of MDOF and equivalent SDOF systems, the comparisons of the results and the graphical representations of the comparisons. Additionally, the comparative investigations of the common approximations to capture the nonlinear static response (MULTI method) are presented in Appendix B.

CHAPTER 2

DESCRIPTION OF FRAMES AND GROUND MOTIONS

2.1 GENERAL

Seven reinforced concrete frames and a total of 100 ground motions were employed in this study to evaluate the influence of idealization of pushover curves on the seismic response of frame structures. The frame set was selected so that there is a uniform distribution of fundamental period. In addition, the ground motion database was intended to cover a wide range of earthquake hazard level that would impose response in elastic as well as inelastic range for the structures analyzed.

The low- to mid-rise frame set used in this study contains two- to eight-story frames having various numbers of bays. Identifying them according to the number of stories and bays, the frames include two two-story-two-bay frames named as F2S2B and F2S2B2, a three-story-two-bay frame called F3S2B, three five story frames having two, four and seven bays and entitled as F5S2B, F5S4B and F5S7B, respectively, and finally an eight-story-three-bay frame termed as F8S3B.

The ground motion record set previously used by Erberik and Cullu [7] was adopted for this study to represent a wide range of seismic hazard level that would reflect the global response of the selected frames by both elastic and inelastic responses. Since the earthquake set was thought to be large enough for obtaining various levels of inelasticity, individual records were employed as unscaled ones.

2.2 DESCRIPTION OF SELECTED FRAMES

Seven reinforced concrete frames which have a diverse fundamental period distribution were selected and analyzed in this study. Among the current frame set depicted in Figure 2.1, F2S2B, F5S4B and F8S3B were designed in California complying with the Uniform Building Code-1982 [11] whereas F2S2B2, F3S2B, F5S2B and F5S7B were selected from the existing structures located in the city of Bursa in Turkey. The eigenvalue analyses of the frames were conducted using OpenSees [15] and the fundamental period of vibration range was found to be between 0.3 and 1.2 seconds. The geometric and sectional properties of the selected frames are presented in Appendix A.1 and the dynamic characteristics of the selected frames are given in Table 2.1.

Table 2.1 Dynamic Characteristics of Selected Frames

FRAME	**Total Mass (t)**	**Fundamental Period T_1 (s)**	**Modal Participation Factor (Γ_1)**	**Modal Mass Factor (α_1)**
F2S2B	275.3	0.59	1.339	0.814
F2S2B2	137.6	0.30	1.339	0.815
F3S2B	226.5	0.45	1.416	0.768
F5S2B	260.2	0.75	1.293	0.794
F5S4B	1007.1	0.95	1.362	0.776
F5S7B	769.1	0.66	1.285	0.804
F8S3B	1816.1	1.20	1.430	0.705

2.3 SELECTED GROUND MOTIONS

For the nonlinear time history analyses of the case study frames, 100 individual ground motions were used in this study and the important features of these ground motions are given in Table 2.2. The earthquake excitations recorded at various sites were selected to represent a large spectrum of strong motion characteristics in terms of Peak Ground Velocity (PGV), Peak Ground Acceleration (PGA) and local site conditions. However, since the reference hazard parameter in Erberik and Cullu [7] was considered as PGV, the database formation was handled accordingly. Consequently, the uniformity of PGV distribution is much more significant than the homogeneity of PGA distribution as shown in Figures 2.2 and 2.3. According to the given features, the distribution of PGV, accepted to be correlating well with inelastic displacement demand, is ranging from 10 to 120 cm/s whereas PGA values fall mostly in the range of 0.1g-1.0g.

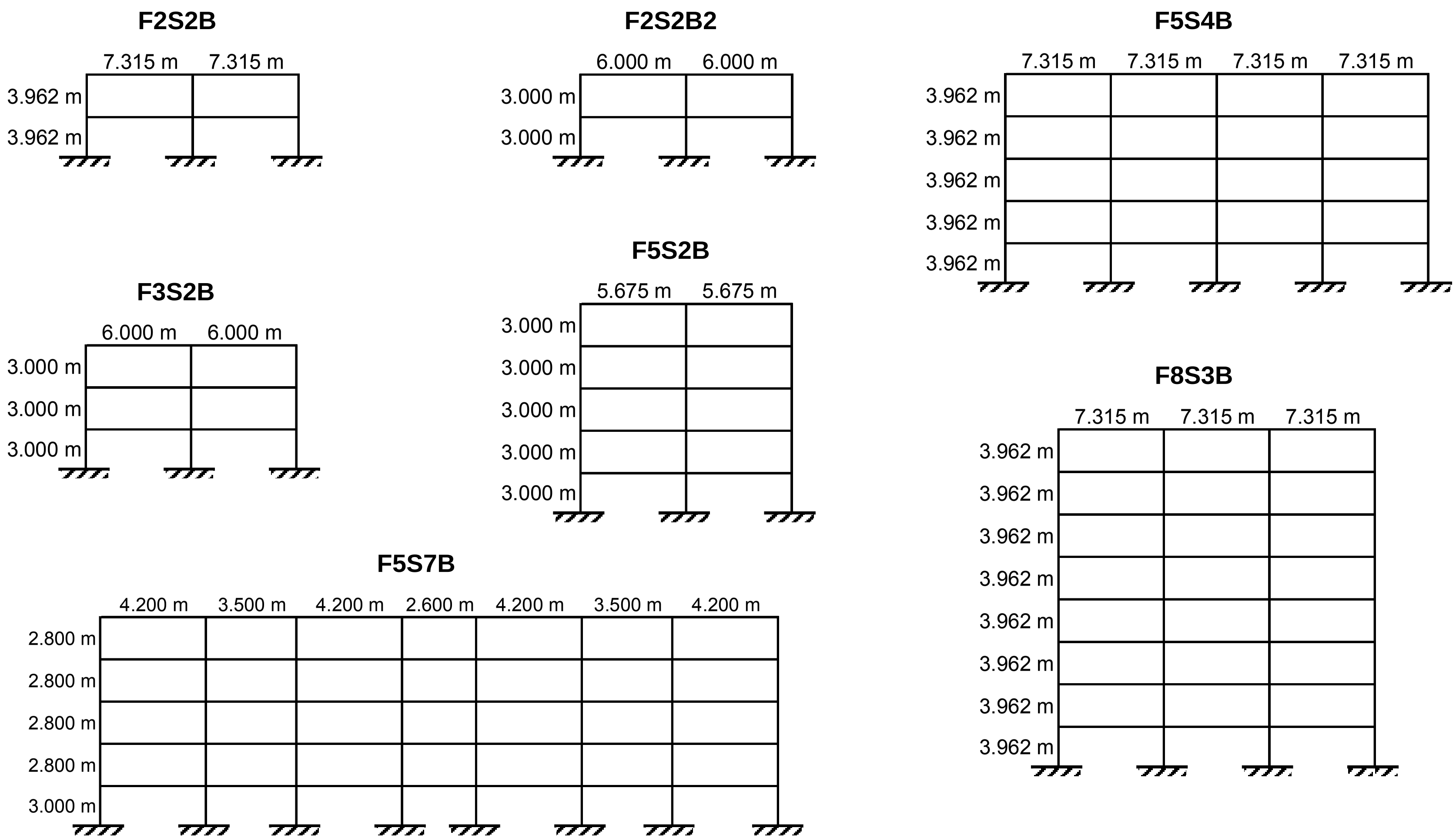

Figure 2.1 General Properties of Selected Frames

Table 2.2 List of Employed Ground Motions

#	Earthquake	Country	Date	Location	Site Geology	SC	Comp	M_s	M_w	ED (km)	HD (km)	CD (km)	PGA (g)	PGV (cm/s)
1	Manjil	Iran	20.06.1990	Building & Housing Research Center, Tehran	Stiff Soil	Z2	NS	7.3	_	234	_	_	0.011	1.09
2	Manjil	Iran	20.06.1990	Building & Housing Research Center, Tehran	Stiff Soil	Z2	EW	7.3	_	234	_	_	0.013	1.24
3	Vrancea	Romania	30.05.1990	Bucharest, Building Research Institute	Alluvium	Z3	NS	6.8	_	162	_	_	0.038	6.45
4	Vrancea	Romania	30.05.1990	Bucharest, Building Research Institute	Alluvium	Z3	EW	6.8	_	162	_	_	0.054	2.08
5	İzmir	Turkey	06.11.1992	Kusadasi Meteorology Station	Stiff Soil		L	6.0	_	41	_	_	0.067	4.34
6	Morgan Hill	USA	24.04.1984	Gilroy Array #7 (Mantelli Ranch)	Alluvium / Sandstone	Z3	90	6.1	6.1	_	_	7.9	0.114	5.76
7	Lazio Abruzzo	Italy	07.05.1984	Cassino-Sant'Elia	Alluvium	Z3	EW	5.8	5.7	23	_	_	0.114	7.90
8	Landers	USA	28.06.1992	Amboy	Stiff Soil	Z2	0	7.5	7.3	_	_	73.2	0.115	17.86
9	Montenegro A.s.	Form. Yug.	24.05.1979	Budva, PTT	Alluvium		NS	6.3	_	8	_	_	0.119	19.24
10	Coalinga	USA	02.05.1983	Parkfield - Cholame 4W	Alluvium / Sandstone	Z2	0	6.5	6.5	_	58.2	_	0.131	10.51
11	Imperial Valley	USA	15.10.1979	El Centro Array #1, Borchard Ranch	Alluvium	Z3	S40E	6.9	6.5	_	_	22.6	0.141	16.43
12	Landers	USA	28.06.1992	Amboy	Stiff Soil	Z2	90	7.5	7.3	_	_	73.2	0.146	20.07
13	Northridge	USA	17.01.1994	Leona Valley, Ritter Ranch	Alluvium	Z3	0	6.8	6.7	_	_	41.4	0.146	14.88
14	Chi Chi	Taiwan	20.09.1999	TCU109	USGS (C)		NS	7.6	7.6	_	_	13.09	0.155	53.07
15	Morgan Hill	USA	24.04.1984	Gilroy Array #2 (Hwy 101 & Bolsa Rd)	Alluvium	Z3	0	6.1	6.1	_	_	11.8	0.157	4.99
16	Horasan	Turkey	30.10.1983	Horasan Meteorology Station	Stiff Soil		EW	6.7	_	33	_	_	0.161	26.02
17	Loma Prieta	USA	18.10.1989	Hayward Muir School	Alluvium	Z3	0	7.1	7.0	_	_	44.9	0.170	13.63
18	Marmara	Turkey	17.08.1999	Kucuk Cekmece	Stiff Soil		NS	7.8	7.4	110	_	59	0.173	8.34
19	Campano-Lucano	Italy	23.11.1980	Calitri	Stiff Soil		EW	6.9	6.5	16	_	_	0.176	27.46
20	Bucharest	Romania	04.03.1977	Bucharest, Building Research Institute	Alluvium		NS	7.1	_	161	_	_	0.202	73.13
21	Manjil	Iran	20.06.1990	Abhar	Soft Soil		T	7.3	_	98	_	_	0.209	55.44
22	Kalamata	Greece	13.09.1986	Kalamata-Prefecture	Stiff Soil		N265	5.8	_	9	_	_	0.215	32.73
23	Northridge	USA	17.01.1994	Downey County Maint. Bldg.	Alluvium	Z3	360	6.8	6.7	_	_	46.2	0.223	12.70
24	Campano-Lucano	Italy	23.11.1980	Brienza	Stiff Soil	Z2	NS	6.9	6.5	43	_	_	0.227	11.27
25	Marmara	Turkey	17.08.1999	İzmit	Rock		EW	7.8	7.4	11	_	8	0.227	54.28
26	Marmara	Turkey	17.08.1999	Yarımca	Soft Soil		EW	7.8	7.4	15	_	3	0.230	84.70
27	Kalamata	Greece	13.09.1986	Kalamata-OTE Building	Stiff Soil		N80E	5.8	_	10	_	_	0.240	31.51
28	Montenegro	Form. Yug.	15.04.1979	Ulcinj, Hotel Olimpic	Stiff Soil		EW	7.0	_	24	_	_	0.241	47.08
29	Landers	USA	28.06.1992	Yermo Fire Station	Alluvium		270	7.5	7.3	_	_	31	0.245	50.81
30	Livermore	USA	27.01.1980	Fagundes Ranch	Alluvium	Z3	270	5.8	_	_	11.3	_	0.250	9.74
31	Chi Chi	Taiwan	20.09.1999	TCU049	USGS (C)		NS	7.6	7.6	_	_	4.48	0.251	61.19
32	San Fernando	USA	09.02.1971	8244 Orion Blvd.	Alluvium		N00W	6.5	6.6	_	_	16.5	0.255	29.80
33	Denizli	Turkey	19.08.1976	Directorate of Public Works and Settlement	Stiff Soil		EW	5.1	_	15	_	_	0.261	15.46
34	Chi Chi	Taiwan	20.09.1999	TCU075, Nantou Tsaotun School	Class D (UBC97)		360	7.6	7.6	_	_	3.4	0.262	35.38
35	Marmara	Turkey	17.08.1999	Gebze	Stiff Soil		NS	7.8	7.4	42	_	15	0.269	45.59

Table 2.2 Continued

#	Earthquake	Country	Date	Location	Site Geology	SC	Comp	M_s	M_w	ED (km)	HD (km)	CD (km)	PGA (g)	PGV (cm/s)
36	Kalamata	Greece	13.09.1986	Kalamata-OTE Building	Stiff Soil		N10W	5.8	_	10	_	_	0.272	23.55
37	Landers	USA	28.06.1992	Joshua Tree Fire Station	Quaternary		90	7.5	7.3	_	_	10	0.284	42.71
38	Alkion	Greece	24.02.1981	Xilokastro, OTE Building	Alluvium		L	6.7	_	19	_	_	0.289	22.72
39	Whittier Narrows	USA	01.10.1987	Fremont School, Alhambra	Alluvium		180	5.8	6.1	_	_	13.9	0.292	21.72
40	Imperial Valley	USA	15.10.1979	Meloland Overpass	Alluvium		270	6.9	6.5	_	_	3.1	0.296	90.45
41	Northridge	USA	17.01.1994	Pacoima Kagel Canyon	Tertiary Sandstone	Z2	90	6.8	6.7	_	_	10.6	0.301	30.95
42	Montenegro	Form. Yug.	15.04.1979	Petrovac, Hotel Oliva	Stiff Soil		EW	7.0	_	25	_	_	0.306	25.31
43	Imperial Valley	USA	15.10.1979	Meloland Overpass	Alluvium		0	6.9	6.5	_	_	3.1	0.314	71.77
44	Dinar	Turkey	01.10.1995	Dinar Meteorology Station	Soft Soil		EW	6.1	6.0	0	_	_	0.319	40.61
45	Marmara	Turkey	17.08.1999	Yarımca	Soft Soil		NS	7.8	7.4	15	_	3	0.322	79.60
46	Loma Prieta	USA	18.10.1989	Gilroy Array #2	USGS (C)	Z3	337	7.1	7.0	_	_	12.1	0.322	39.09
47	Loma Prieta	USA	18.10.1989	Saratoga	Alluvium		90	7.1	7.0	_	_	4.1	0.322	43.60
48	Chi Chi	Taiwan	20.09.1999	TCU075, Nantou Tsaotun School	Class D (UBC97)		90	7.6	7.6	_	_	3.4	0.331	102.02
49	Marmara	Turkey	17.08.1999	Düzce	Soft Soil		NS	7.8	7.4	107	_	11	0.337	60.59
50	Imperial Valley	USA	15.10.1979	El Centro Array #6, Huston Road	Alluvium		S40E	6.9	6.5	_	_	3.5	0.339	66.47
51	Northridge	USA	17.01.1994	W Pico Canyon Blvd, Newhall	Nonmarine Deposit		N44W	6.8	6.7	_	_	9.4	0.355	59.87
52	Chi Chi	Taiwan	20.09.1999	CHY006	USGS (C)		EW	7.6	7.6	_	_	14.9	0.364	55.41
53	Loma Prieta	USA	18.10.1989	Gilroy Array #2	USGS (C)	Z3	67	7.1	7.0	_	_	12.1	0.367	32.92
54	Imperial Valley	USA	15.10.1979	El Centro Array #5, James Road	Alluvium		S50W	6.9	6.5	_	_	5.2	0.367	95.89
55	Northridge	USA	17.01.1994	Saticoy	Alluvium		90	6.8	6.7	_	_	12.9	0.368	28.92
56	Loma Prieta	USA	18.10.1989	Hollister - South St. And Pine Dr.	Alluvium		0	7.1	7.0	_	_	17.2	0.369	62.78
57	Northridge	USA	17.01.1994	Santa Monica, City Hall Grounds	Alluvium	Z3	360	6.8	6.7	_	_	27.4	0.370	24.91
58	Chi Chi	Taiwan	20.09.1999	TCU074, Nantou Nanguang School	Class D (UBC97)		360	7.6	7.6	_	_	13.8	0.370	46.29
59	Erzincan	Turkey	13.03.1992	Erzincan	Soil		EW	7.3	7.1	_	_	2	0.469	92.05
60	Whittier Narrows	USA	01.10.1987	Cedar Hill Nursery, Tarzana	Alluvium / Siltstone	Z1	0	5.8	6.1	_	_	41.1	0.405	19.16
61	Marmara	Turkey	17.08.1999	Sakarya	Stiff Soil / Rock		EW	7.8	7.4	40	_	7	0.407	79.80
62	Düzce	Turkey	12.11.1999	Düzce	Soft Soil		NS	7.3	7.1	9.3	_	7	0.410	65.76
63	Chi Chi	Taiwan	20.09.1999	TCU076	Class D (UBC97)		NS	7.6	7.6	_	_	3.2	0.416	64.16
64	Imperial Valley	USA	15.10.1979	El Centro Array #6, Huston Road	Alluvium		S50W	6.9	6.5	_	_	3.5	0.437	113.11
65	Loma Prieta	USA	18.10.1989	Gilroy Array #1	Rock	Z1	90	7.1	7.0	_	_	2.8	0.442	33.84
66	Montenegro	Form. Yug.	15.04.1979	Petrovac, Hotel Oliva	Stiff Soil		NS	7.0	_	25	_	_	0.454	38.82
67	Erzincan	Turkey	13.03.1992	Erzincan	Soil		EW	7.3	7.1	_	_	2	0.469	92.05
68	Loma Prieta	USA	18.10.1989	Capitola Fire Station	Alluvium		0	7.1	7.0	_	_	15.9	0.472	36.15
69	Northridge	USA	17.01.1994	Saticoy	Alluvium		180	6.8	6.7	_	_	12.9	0.477	61.48
70	Northridge	USA	17.01.1994	Rinaldi Receiving Station	Alluvium	Z3	N41W	6.8	6.7	_	_	8.6	0.480	80.33

Table 2.2 Continued

#	Earthquake	Country	Date	Location	Site Geology	SC	Comp	M_s	M_w	ED (km)	HD (km)	CD (km)	PGA (g)	PGV (cm/s)
71	Kobe	Japan	16.01.1995	Nishi-Akashi	USGS (D)	Z4	90	_	6.9	_	_	11	0.503	36.60
72	Loma Prieta	USA	18.10.1989	Saratoga	Alluvium		0	7.1	7.0	_	_	4.1	0.504	41.35
73	Düzce	Turkey	12.11.1999	Düzce	Soft Soil		EW	7.3	7.1	9.3	_	7	0.513	86.05
74	Northridge	USA	17.01.1994	Katherine Rd, Simi Valley	Alluvium		N90E	6.8	6.7	_	_	14.3	0.513	44.56
75	Northridge	USA	17.01.1994	Castaic Old Ridge Road	Sandstone		360	6.8	6.7	_	_	24.1	0.514	52.56
76	Imperial Valley	USA	15.10.1979	El Centro Array #5, James Road	Alluvium		S40E	6.9	6.5	_	_	5.2	0.550	49.71
77	Northridge	USA	17.01.1994	Slymar, Converter Station	Alluvium	Z3	N38W	6.8	6.7	_	_	8.7	0.580	107.48
78	Northridge	USA	17.01.1994	Newhall LA County Fire Station	Alluvium	Z3	90	6.8	6.7	_	_	10.9	0.583	74.84
79	Cape Mendocino	USA	25.04.1992	Petrolia, General Store	Alluvium		0	7.1	7.0	_	_	15.9	0.589	48.30
80	Northridge	USA	17.01.1994	Newhall LA County Fire Station	Alluvium		360	6.8	6.7	_	_	10.9	0.589	94.72
81	Northridge	USA	17.01.1994	Jensen Filter Plant	Alluvium		292	6.8	6.7	_	_	8.6	0.593	99.28
82	Chi Chi	Taiwan	20.09.1999	TCU074, Nantou Nanguang School	Class D (UBC97)		90	7.6	7.6	_	_	13.8	0.595	74.64
83	Kobe	Japan	16.01.1995	JMA	USGS (B)	Z2	EW	_	6.9	_	_	1	0.629	75.04
84	Loma Prieta	USA	18.10.1989	Corralitos	Landslide Deposit		0	7.1	7.0	_	_	2.8	0.630	55.20
85	Chi Chi	Taiwan	20.09.1999	CHY028	USGS(C)		EW	7.6	7.6	_	_	7.31	0.653	72.78
86	Chi Chi	Taiwan	20.09.1999	TCU071	USGS (D)		NS	7.6	7.6	_	_	4.9	0.655	69.38
87	Cape Mendocino	USA	25.04.1992	Petrolia, General Store	Alluvium		90	7.1	7.0	_	_	15.9	0.662	89.45
88	Kobe	Japan	16.01.1995	Takarazu	USGS (D)		0	_	6.9	_	_	1.2	0.693	68.28
89	Kobe	Japan	16.01.1995	Takarazu	USGS (D)		90	_	6.9	_	_	1.2	0.694	85.25
90	Northridge	USA	17.01.1994	Katherine Rd, Simi Valley	Alluvium		N00E	6.8	6.7	_	_	14.3	0.727	51.11
91	Northridge	USA	17.01.1994	Sepulveda VA Hospital	Alluvium		270	6.8	6.7	_	_	9.5	0.753	84.85
92	Düzce	Turkey	12.11.1999	Bolu	Soil		NS	7.3	7.1	39	_	5.5	0.754	58.25
93	Düzce	Turkey	12.11.1999	Bolu	Soil		EW	7.3	7.1	39	_	5.5	0.822	66.92
94	Kobe	Japan	16.01.1995	JMA	USGS (B)	Z2	NS	_	6.9	_	_	1	0.833	90.70
95	Tabas	Iran	16.09.1978	Tabas	Stiff Soil		N74E	7.3	_	52	_	_	0.914	90.23
96	Northridge	USA	17.01.1994	Sepulveda VA Hospital	Alluvium		360	6.8	6.7	_	_	9.5	0.939	76.60
97	Northridge	USA	17.01.1994	Tarzana Cedar Hill Nursery	Alluvium	Z1	360	6.8	6.7	_	_	16.7	0.990	77.18
98	Tabas	Iran	16.09.1978	Tabas	Stiff Soil	Z2	N16W	7.3	_	52	_	_	1.065	80.53
99	Morgan Hill	USA	24.04.1984	Coyote Lake Dam	Rock		285	6.1	6.1	_	_	1.5	1.298	80.79
100	Northridge	USA	17.01.1994	Tarzana Cedar Hill Nursery	Alluvium	Z1	90	6.8	6.7	_	_	16.7	1.778	110.16

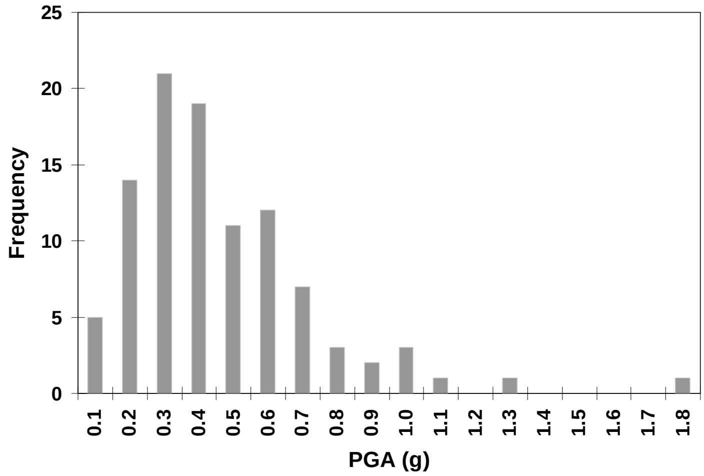

Figure 2.2 PGA Distribution of the Ground Motion Bin

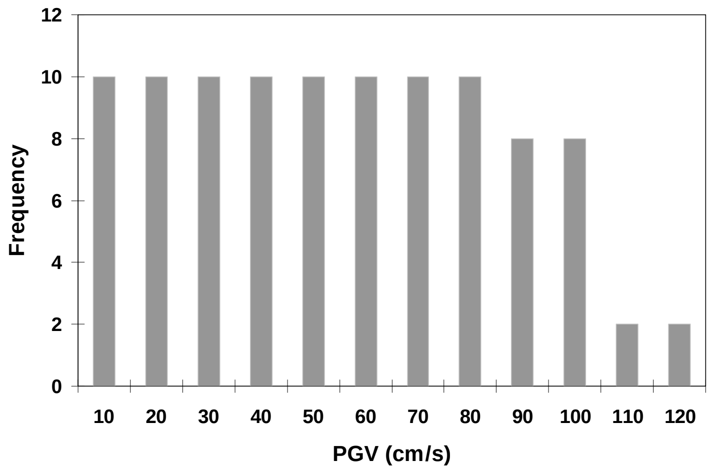

Figure 2.3 PGV Distribution of the Ground Motion Set

As depicted in Figures 2.4-2.6, the moment magnitude of the dataset covers a range of 6.1-7.6 and both near and far field ground motions constitute the strong motion database. For the records whose moment magnitudes were not available in the list, a conversion formula derived by Deniz [6], as given in Eqn 2.1, was adopted:

$$M_w = 0.54 \cdot M_s + 2.81 \qquad (2.1)$$

According to this formula, lower bound of moment magnitude M_w can be computed from the surface wave magnitude M_s. The calculations were made and included in the statistical representation of records, accordingly.

Although near field records with distance less than 20 km seem to dominate the set, extreme ground motion records due to very severe near field and soil site effects were not included. Considering the main attributes described along with the mean and 84-th percentile 5% damped elastic pseudo-velocity and pseudo-acceleration response spectra plotted in Figures 2.7 and 2.8, respectively, this wide bin of ground motions is expected to push the structures into various degrees of inelasticity.

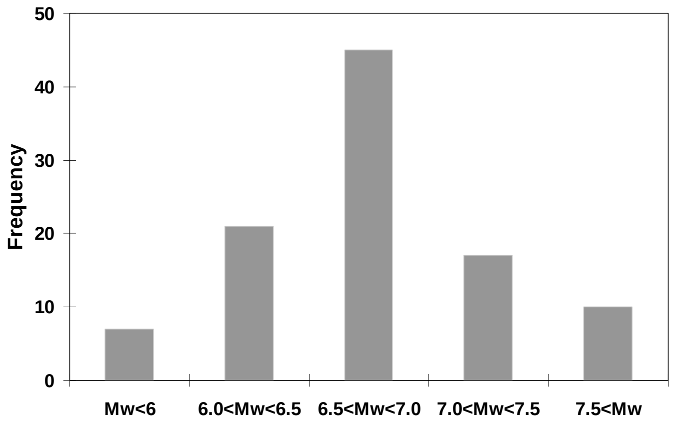

Figure 2.4 Moment Magnitude Distribution

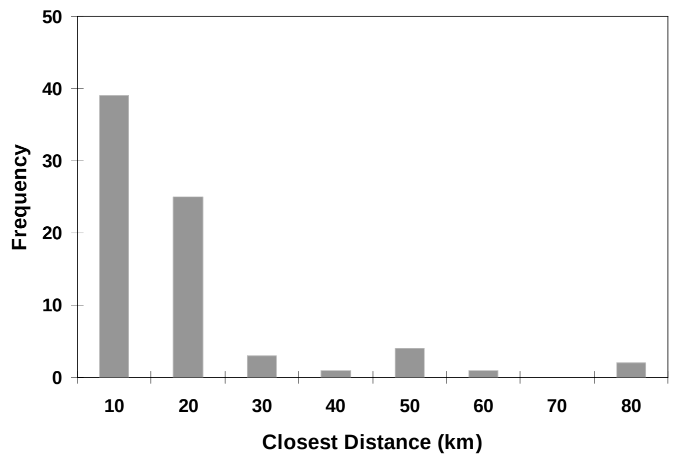

Figure 2.5 Closest Distance to Fault Distribution

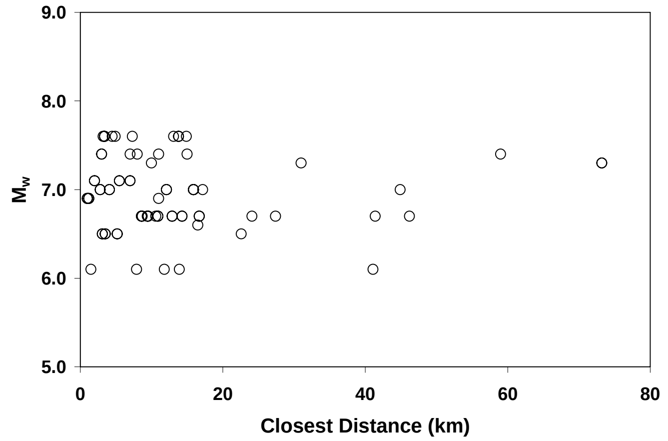

Figure 2.6 Moment Magnitude versus Closest Distance Plot

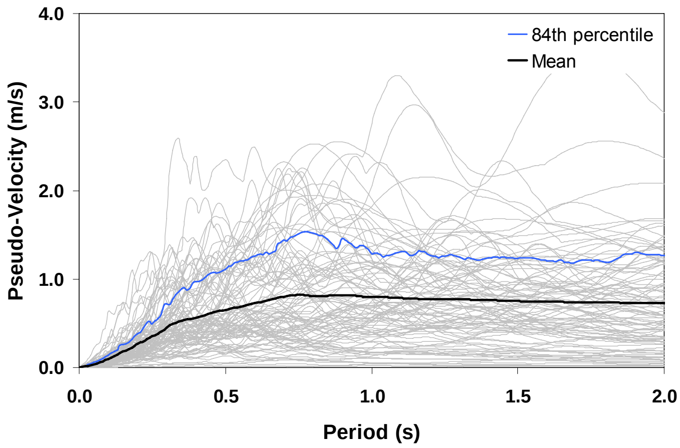

Figure 2.7 Mean and 84-th percentile Pseudo-Velocity Response Spectra for Ground Motions (5% Damped)

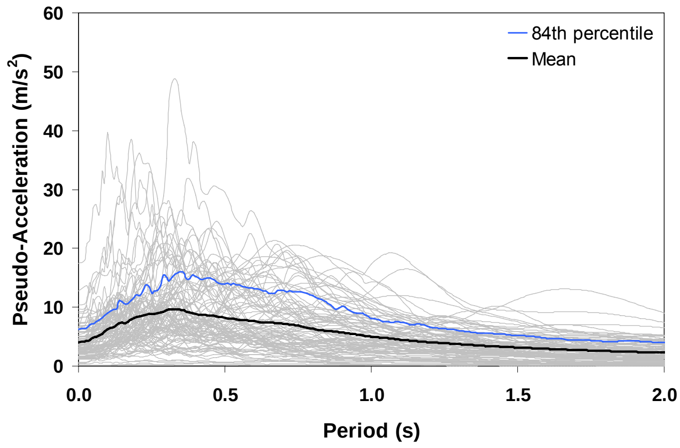

Figure 2.8 Mean and 84-th percentile Pseudo-Acceleration Response Spectra for Ground Motions (5% Damped)

CHAPTER 3

ANALYSES OF FRAMES

3.1 GENERAL

The influence of idealized capacity curves of frames on their seismic response was investigated utilizing the well-known open-source software framework OpenSees [15] that was mainly developed by the University of California at Berkeley. The reason for choosing OpenSees as the analysis tool in this study is its increasing use by the researchers for simulation applications in earthquake engineering. Moreover, its ability to represent the pushover curves as multi-linear segments made it possible that all analyses can be carried out in OpenSees.

As will be described alternately in the foregoing sections, three types of analyses were conducted. Firstly, the two dimensional models of the selected frames were prepared and nonlinear time history analyses were carried out by using the selected ground motions. The seismic responses such as roof displacements, story drifts and shear forces obtained from these analyses for each frame were considered as 'exact' for the further stages of the study. After computing 'exact' results, nonlinear static analyses were conducted to acquire the global response capacity for each frame through invariant lateral load patterns. From the capacity curve of each frame, equivalent SDOF systems were formed and analyzed under the same strong motion dataset. Responses obtained from the approximate analyses using equivalent SDOF systems were then compared with the corresponding 'exact' values to investigate the effects of capacity curve idealization.

3.2 ANALYSES WITH OPENSEES

OpenSees [15] is an open-source software framework developed for general purpose finite element analysis and its community code has been continuously improved by the researchers worldwide. Its various modeling and analysis options in a sturdy environment that could be easily modified for several needs have made OpenSees the promising program for both structural analysis and simulation tasks in recent years. With taking the advantage of the ability to define structural components in either element, section or fiber level using the more versatile command-driven scripting language and various analysis options such as static pushover and dynamic time series analyses, OpenSees has been selected as the only tool for this study.

One fundamental feature of this free analysis program that was used in the analyses is the nonlinear modeling of frame components through fiber-based nonlinear beam-column elements [21]. Unlike SAP2000 [5] which is a well-known software in engineering practice, OpenSees has the capability of modeling distributed plasticity and the ability to represent the nonlinear static and dynamic behavior of structural elements with a single element type.

The fiber beam-column element developed by Taucer *et al.* [21] forms the basis of OpenSees' nonlinear beam-column element. This flexibility-based fiber element type was once proposed to be a reliable and computationally efficient beam-column finite element model for the analysis of reinforced concrete members under cyclic loading conditions that induce biaxial bending and axial force and has been intensively used for 15 years.

As stated in the research report published in 1991 [21], the element is discretized into longitudinal steel and concrete fibers such that the section force-deformation relation is derived by integration of the uniaxial stress-strain relation of the fibers. The nonlinear behavior of the element derives entirely from the nonlinear stress-strain relation of the steel and concrete fibers, thus this property eliminates the necessity for the input of force-deformation of the element.

The beam-column element is based on the assumption that deformations are small and that plane sections remain plane during the loading history. In addition to this, the deformations due to shear and torsion are neglected in the formulation of this element. It was also expressed in the report that for the accuracy of the results which represent the hysteretic behavior of the elements, the number of sub-divisions called fibers and the control sections that are needed to form the flexibility matrices of the elements from the fibers should be wisely defined. Following the recommendations and using the interpretations of basic sensitivity analyses, the number of integration points for beams and columns were selected as four and six, respectively. Furthermore, the number of sub-divisions of a single section which is not very influential along the width of the section in a two dimensional problem was defined in a manner that both optimum accuracy and minimum calculation time considerations were satisfied. A representation of a fiber element, shown in Figure 3.1, also designates the necessity of defining reliable constitutive models which are abundantly available in OpenSees.

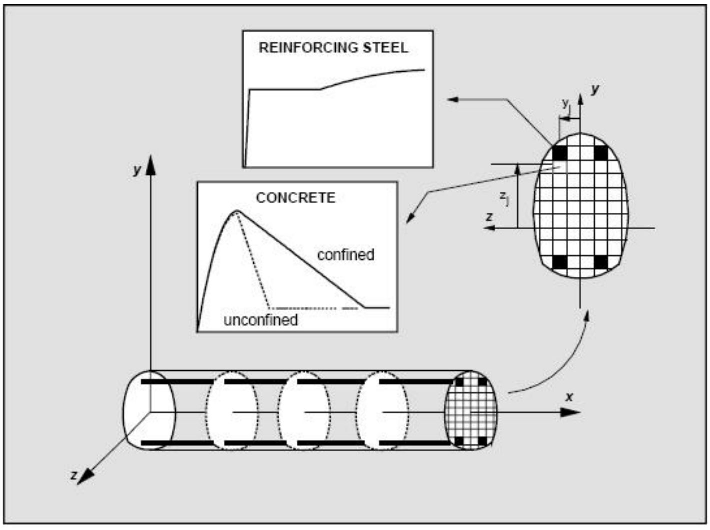

Figure 3.1 Graphical Representation of a Fiber Element [21]

As depicted in Figure 3.1, the unconfined and confined concrete models, and reinforcing steel constitutive models were defined separately. The concrete models, which were selected as Concrete01 uniaxial material type, are based on Kent-Scott-Park model (Kent and Park [13], Scott *et al.* [19]) with degraded linear unloading/reloading according to the work of Karsan and Jirsa [12] and neglect the tensile strength. The model requires 28-day compressive and crushing strengths, concrete strains at maximum and crushing strengths as input parameters (Figure 3.2). The parameters were calculated according to the model expressed and given in Appendix A.1 along with the frames they are related to.

The reinforcements of the reinforced concrete components were modeled as single steel fibers across the section and the constitutive model was selected as Steel01 which is a relatively simple model requiring few parameters. The general characteristic of this model can be expressed as a bilinear steel material model with a kinematic hardening and apart from the yield strength which differs for each frame, the initial elastic tangent and strain hardening ratio for all over the study were defined as 200000 MPa and 0.005, respectively.

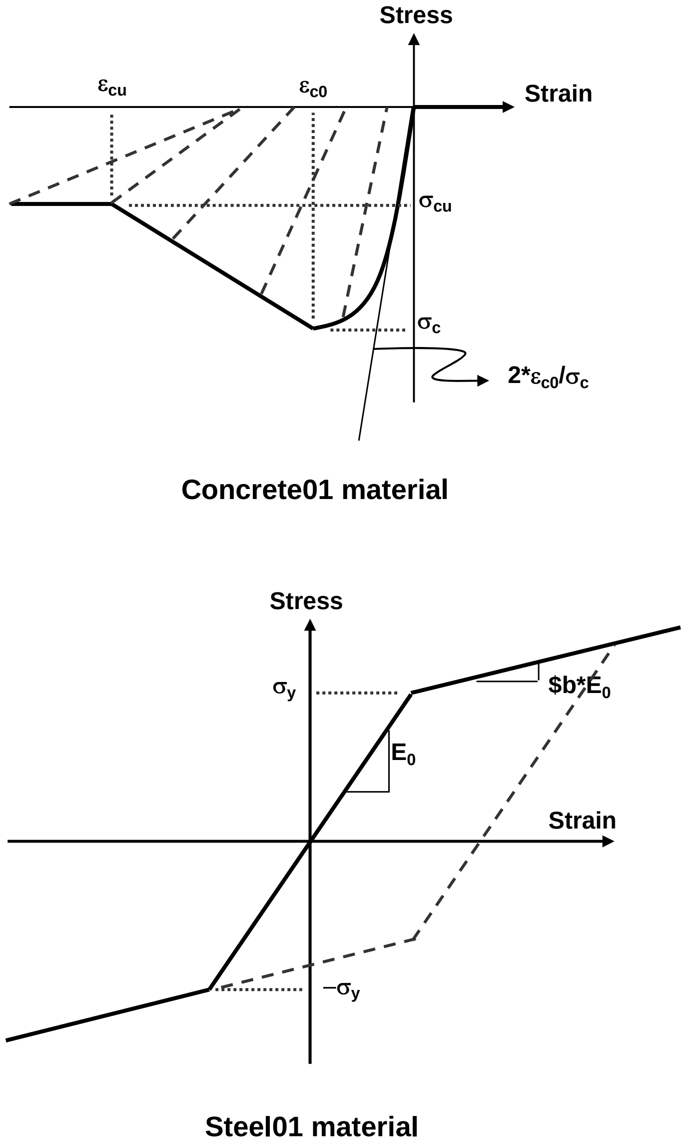

Figure 3.2 Concrete01 and Steel01 Material Models [15]

3.3 NONLINEAR TIME HISTORY ANALYSES

In order to evaluate the effects of idealization on seismic response, certain seismic response values based on approximate analyses must be compared with the ones obtained from the complex analyses which are detailed enough to include the cyclic behavior of the structures analyzed and the characteristics of strong ground motions employed. Therefore, the case study frames were analyzed using the selected earthquakes by utilizing OpenSees to represent the complex structural behavior under seismic excitations. The details regarding the modeling and other assumptions are presented in the next section.

3.3.1 Modeling and Assumptions

Using the command language of OpenSees, two dimensional structural models rigidly connected at the ground floor were prepared utilizing the general properties of the frames given in Appendix A.1. All frame elements based on centerline dimensions were modeled as fiber based *NonlinearBeamColumn* elements taking the advantage of distributed plasticity models [15]. Since the fiber cross-sections make it easy to define confined regions of concrete, the confinement effect of transverse reinforcement was taken into account. Although details about the transverse reinforcement are not given in Appendix A.1, minimum amounts required by the codes each frame complies with were calculated and assumed to be present in the case study frames. The nonlinear concrete model parameters for both unconfined and confined regions were then computed according to Modified Kent and Park [13]. After obtaining the concrete model parameters, the cross-sections were defined accordingly using the yield strength and the other parameters of the reinforcements, given previously.

Since the frame elements were defined as massless type, the seismic mass of each floor due to dead loads and 25% of live loads was lumped at the mass center of corresponding story. The rigid diaphragm action and P-Δ effects, however, were ignored for the frames due to their insignificant effects.

Concerning the viscous damping of the structural system under seismic excitations, the damping phenomenon was represented using Rayleigh Damping. The Rayleigh Damping for the selected frames was calculated assuming 5% damping ratio and stiffness proportional damping. Mass proportional damping, however, was neglected due to its insignificant effect.

3.3.2 Nonlinear Time History Analyses Results

After completing the modeling of the two dimensional frames, nonlinear time history analyses were carried out using the ground motion data presented in Chapter 2. In the analyses, tolerance values, which affect element and global convergences in nonlinear analyses, were defined carefully to obtain accurate results at the expense of calculation time. During the analyses, certain responses such as element forces, nodal displacements and story drifts were recorded and then, processed to obtain the maximum base shear ‘V’, maximum top displacement 'Δ' and maximum inter-story drift ratio 'MIDR' in absolute values for each ground motion. For the non-converging cases, the results obtained were not included in the evaluations. It was observed during the post-processing stage that maximum base shear and top displacement couples did not occur at the same time step. Apart from these, when finding the maximum inter-story drift ratio under an earthquake for each frame, the story level was not taken into account and the highest one regardless of floor level was considered as the 'critical' one. This approach was based on the fact that the interpretations using the maximum inter-story drift ratio would be much more helpful for global behavior and performance-based design rather than the assessment of performance of individual floor levels. The earthquake excitation induced responses of the frames obtained from the nonlinear time history analyses are summarized in tables which can be found in Appendix A.2.

3.4 NONLINEAR STATIC ANALYSES

The nonlinear time history analysis is complex in its nature due to the fact that it requires realistic cyclic modeling of structural components and the results are very sensitive to the ground motions employed for this type of analysis. Moreover, the use of large numbers of strong motions in various characteristics to obtain a global structural behavior of the frame analyzed makes it even more difficult to handle with the large amount of data to be stored, processed and interpreted. The long computation time required for the nonlinear analyses with so many excitations also hinders the usage of nonlinear time history analysis. Considering the drawbacks of this analysis method, engineering profession prefers simplified nonlinear analysis techniques namely nonlinear static analyses. As this study partly focuses on the nonlinear static analyses by carrying out research into the effects of idealized pushover curves on seismic response, pushover analysis was also utilized to achieve the global behavior of the selected frames. The assumptions and modeling issues with the details of nonlinear static analyses conducted in this study will be discussed next.

3.4.1 Modeling and Assumptions

The nonlinear static analyses of the previously mentioned two-dimensional systems were also carried out in OpenSees using the same models developed for nonlinear time history analyses, because the fiber based nonlinear beam-column elements in OpenSees with nonlinear stress-strain relationships and cyclic rules made it easy to use single model for both nonlinear static and dynamic analyses. Moreover, the accuracy of the results was thought to be increased by using the advantage of distributed plasticity that reflects the nonlinear behavior of the fibers across the element length rather than representing the nonlinearity of the fibers at lumped plasticity regions (hinges). Another advantage of fiber based elements is the elimination of moment-curvature or moment-rotation inputs that dictate the major characteristics of the elements modeled.

A disadvantageous detail about the nonlinear modeling of reinforced concrete elements that must be expressed is that since the rupture of reinforcement could not have been defined and taken into account with Steel01 model, the nonlinear behavior of the elements in high inelastic ranges might not be so accurate. However, this phenomenon was disregarded, because the crushing of concrete occurred well before longitudinal steel rupture.

Three different invariant lateral load patterns were applied on the two-dimensional models to reflect the global behavior of the frames. 'Uniform', 'Triangular' and 'Elastic First Mode' lateral load patterns were selected, as the first two generally result in upper and lower bound curves and the last represents the likely distribution of inertial forces due to first mode response of the structure which is assumed to be predominant over the other modes of vibration. The details of lateral load pattern calculations are described as follows:

- **'Uniform' Lateral Load Pattern**

The lateral force applied at each story is proportional to the mass of that story level, as given in Eqn. 3.1:

$$F_i = \frac{m_i}{\sum_i m_i} \tag{3.1}$$

where F_i and m_i denote the lateral force applied and the mass at that story, respectively.

- **'Triangular' Lateral Load Pattern**

The lateral force applied at each story is proportional to the story number of that story level, as described in Eqn. 3.2:

$$F_i = \frac{i}{\sum_i i} \tag{3.2}$$

where F_i and i denote the lateral force applied at that story and the story number, respectively.

- **'Elastic First Mode' Lateral Load Pattern**

The lateral force applied at each story is proportional to the product of the mass and the amplitude of the elastic first mode of that story, as expressed in Eqn. 3.3:

$$F_i = \frac{m_i \cdot \phi_i}{\sum_i (m_i \cdot \phi_i)} \tag{3.3}$$

where F_i, m_i and ϕ_i denote the lateral force applied at that story, story mass and the amplitude of the elastic first mode at that level, respectively.

The lateral force profiles of the case study frames determined according to the patterns described above are illustrated in Figure 3.3. Note that the lateral forces are proportioned to establish unit base shear at the ground level.

3.4.2 Nonlinear Static Analyses Results

The pushover analyses were conducted in a scheme that gravity analyses due to dead loads and 25% of the live loads were first carried out and then, lateral load patterns mentioned were applied and increased to obtain the global behavior of the frames. The gravity analyses were conducted by force-controlled algorithm, whereas the lateral pushover analyses were done by displacement-controlled one to push the frames to 2.5% global drift which was considered to be close to the global drift capacity of the frames employed. The normalized capacity curves of the frames, whose general properties regarding total weight and total height are given in Table 3.1, are illustrated along with the nonlinear time history results in Figures 3.4-3.6.

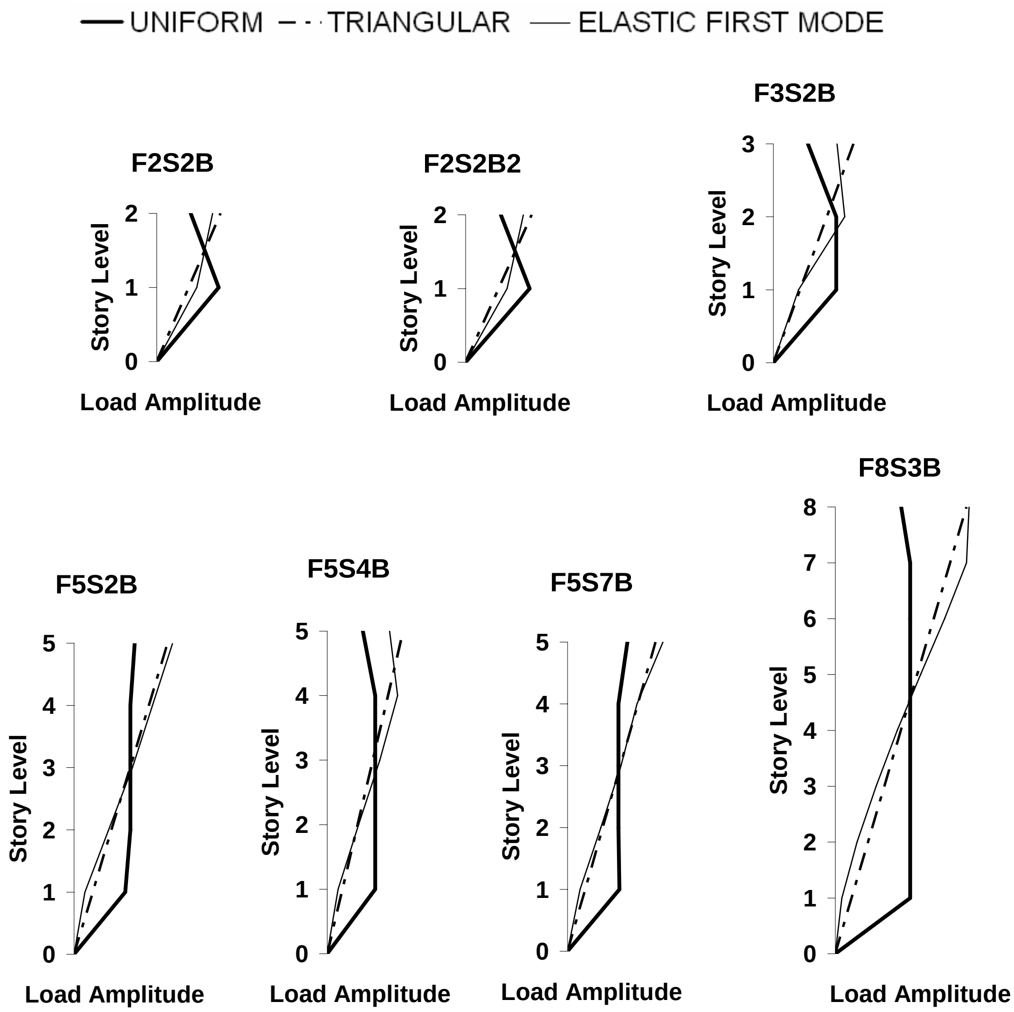

Figure 3.3 Height-wise Distribution of Lateral Load Patterns
for the Case Study Frames

Table 3.1 Total Weight and Height of the Selected Frames

Frame	Total Weight (kN)	Total Height (m)
F2S2B	2700.25	7.92
F2S2B2	1350.13	6.00
F3S2B	2221.76	9.00
F5S2B	2552.33	15.00
F5S4B	9879.85	19.81
F5S7B	7545.07	14.20
F8S3B	17815.65	31.70

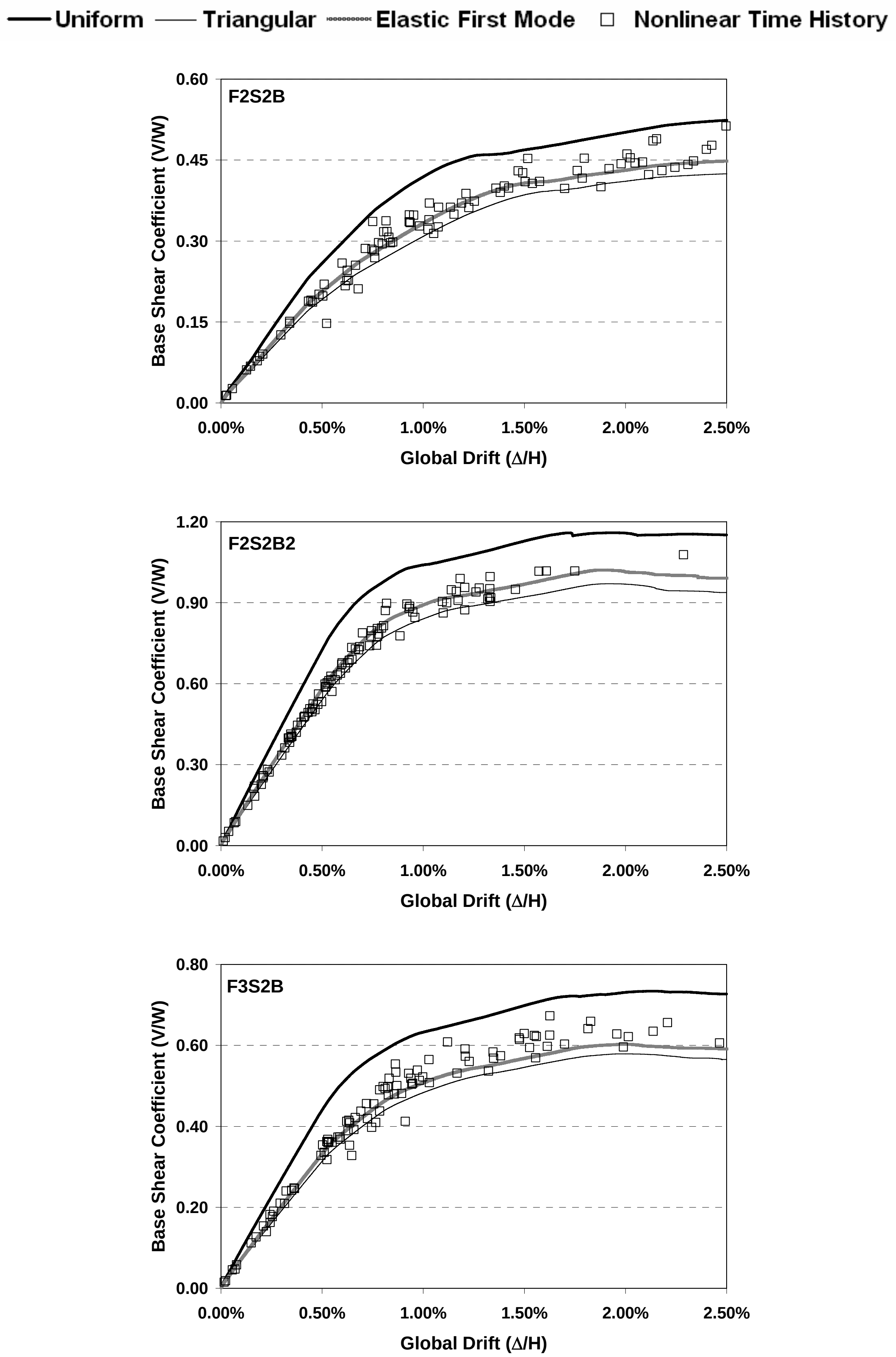

Figure 3.4 Capacity Curves of Frames 'F2S2B', 'F2S2B2' and 'F3S2B' with Nonlinear Time History Analysis Results

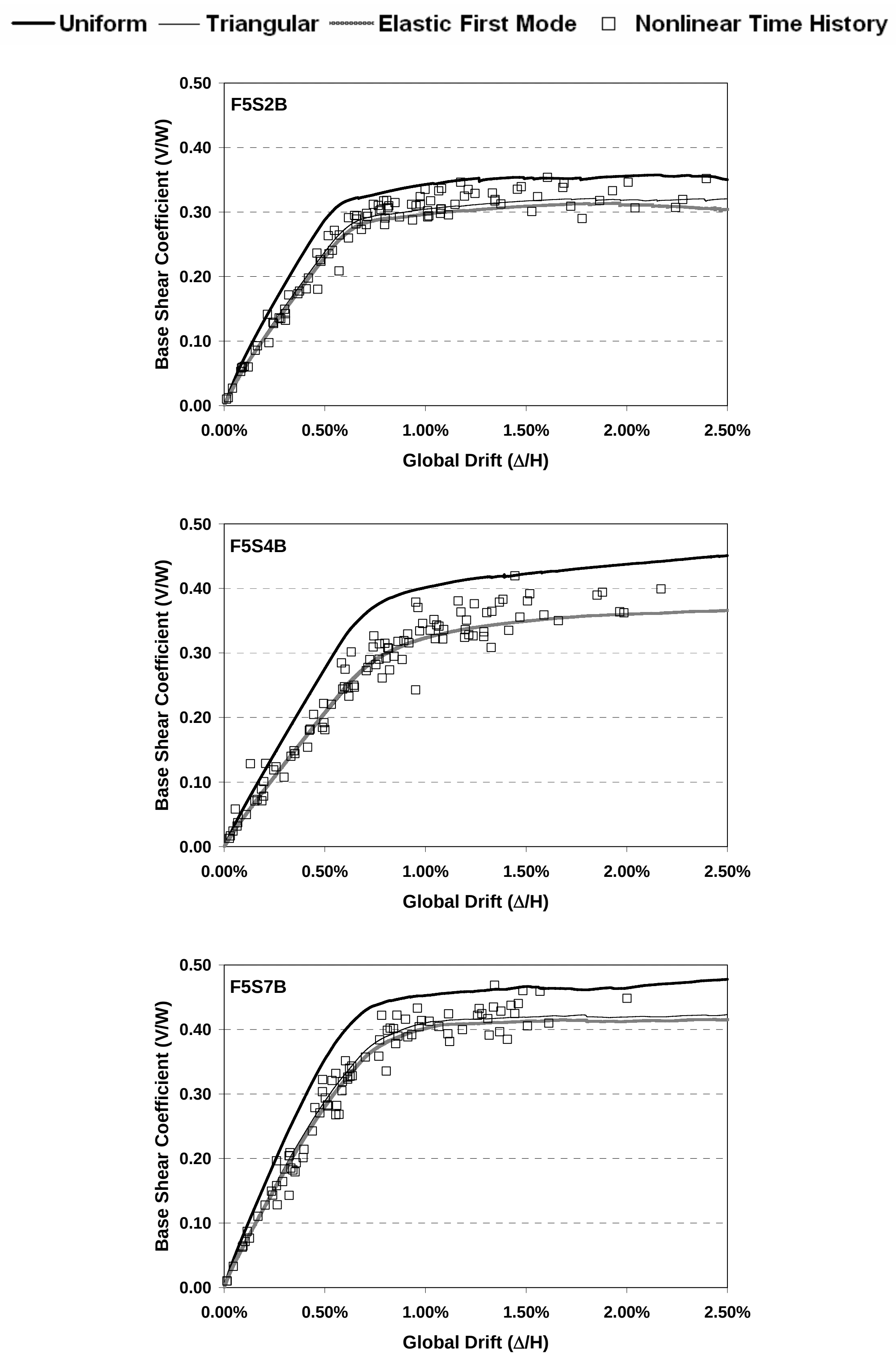

Figure 3.5 Capacity Curves of Frames ‘F5S2B’, ‘F5S4B’ and ‘F5S7B’ with Nonlinear Time History Analysis Results

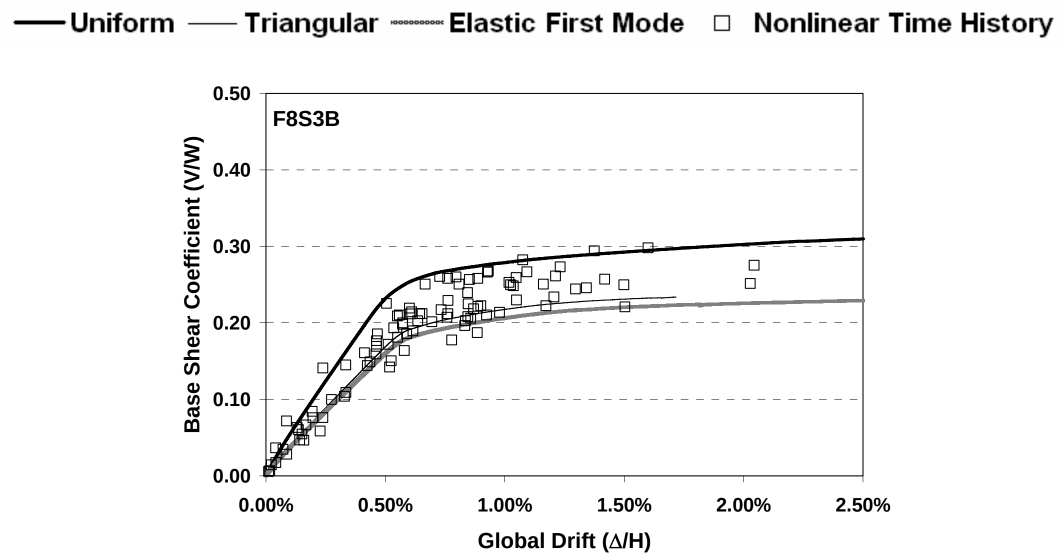

Figure 3.6 Capacity Curves of Frame 'F8S3B' with Nonlinear Time History Analysis Results

Considering the pushover curves of the frames with the nonlinear time history results, the general wisdom that first mode and triangular load patterns lead to close curves and that the uniform and triangular patterns result in upper and lower bound curves was generally revealed by these results. It is also obvious in these figures that the selected earthquake excitations impose elastic as well as inelastic demands on all frames.

Under elastic first mode lateral load pattern, the height-wise distribution of inter-story drift ratios at specified global drift levels, as presented in Figure 3.7, supported the common sense that low-rise frames have a uniform drift distribution and maximum drift ratio generally occurs at the second floor of mid-rise frames. Additionally, maximum drift was observed at middle stories of the relatively high rise frame. The general trend of height-wise drift distribution in the elastic range for each frame was also preserved at high deformation levels.

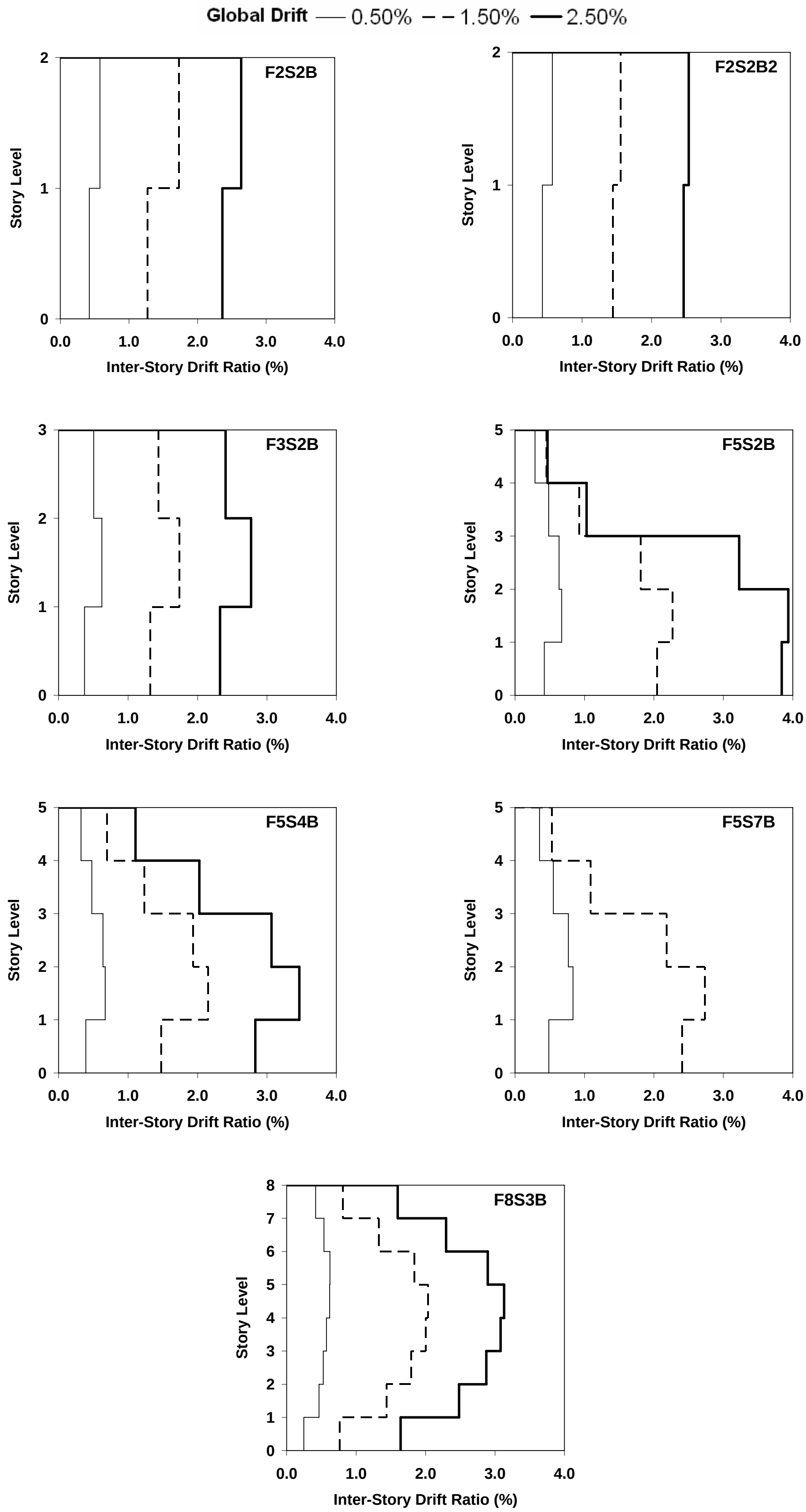

Figure 3.7 Height-wise Distribution of Inter-Story Drift Ratios

3.5 SINGLE DEGREE OF FREEDOM ANALYSES

Among the simplified nonlinear analysis methods, Capacity Spectrum Method of ATC-40 [3] and Displacement Coefficient Method of FEMA-356 [10], of which the concepts have been recently improved by FEMA-440 [4], are the most widely utilized nonlinear static analysis methods to determine the seismic displacement demand of a given structure. The target displacement, that is the expected maximum displacement demand of the structure under a ground motion, is found in the expense of accuracy by disregarding the complex hysteretic behavior of the structures and the intricate characteristics of ground motions to some extent. It is later used to predict the seismic demand in terms of forces and deformations at target displacement. Therefore, the accuracy of determining the displacement demand certainly affects the accuracy of the approximate seismic demand parameters using pushover analysis results.

Apart from the two methods mentioned above, simplified nonlinear dynamic analysis using equivalent SDOF can also be employed to determine the maximum global displacement demand of a structure under an individual earthquake of particular interest. Since this approximate procedure employs the ground motion itself rather than a design spectrum which is mostly used in nonlinear static analyses, the accuracy of the displacement demand is generally higher than the one obtained by nonlinear static analysis methods which have certain additional assumptions. In addition, using the proper modeling of hysteretic characteristics of the structure also increases the accuracy of the results.

In the context of this study, the effects of idealization methods on seismic demand were studied employing the simplified nonlinear dynamic analysis method. The reason behind choosing this simplified method and neglecting the others was the fact that by conducting nonlinear time history analyses using equivalent SDOF systems, the further simplifications and assumptions that are present in nonlinear static analysis techniques were eliminated and thus, the effects would better be presented.

Based on the elastic first mode lateral load dependent pushover analyses previously presented, the capacity curve of each frame was simplified using four alternatives of linearization methods namely MULTI, ATC, FEMA and 75%V_y. Using these simplified force-deformation curves, equivalent SDOF systems were obtained and analyzed under the same ground motion database as MDOF nonlinear time history analyses. Using the elastic stiffnesses of the simplified systems, linear elastic dynamic analyses were also conducted for the ductility and force reduction factor calculations due to each idealization method for each frame.

The underlying principles for deriving the properties of equivalent SDOF from the corresponding MDOF, the alternatives of idealization methods of capacity curves and the results obtained from simplified nonlinear dynamic analyses will be presented in the following sections.

3.5.1 Equivalent SDOF from MDOF

The basic properties of equivalent SDOF system in this study were obtained by using the approach presented in ATC-40 [3]. In this approach, MDOF system is represented by an equivalent SDOF system having an effective mass (M^*), an effective period (T_{eff}) and thus an effective stiffness ($K^* = \frac{4\pi^2 M^*}{T_{eff}^2}$) assuming that the deflected shape of MDOF system is reflected by the elastic first mode of the structure (Figure 3.8).

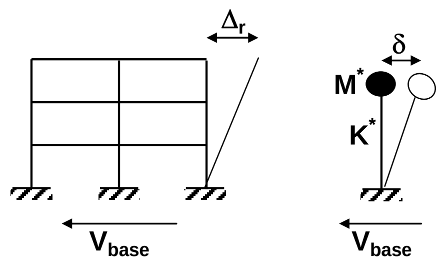

Figure 3.8 MDOF System Represented by Equivalent SDOF System
(ATC-40 [3])

A capacity curve of the overall structure is obtained by performing a pushover analysis in the first step of determining the force-displacement relationship of equivalent SDOF system. The original curve is then converted to an approximate bi-linear shape using the alternative methods described earlier. As the next step, the bi-linear capacity curve is converted to acceleration-displacement response spectrum (ADRS) format using Eqn.s 3.4 and 3.5 (Figure 3.9):

$$Sa = \frac{V}{\alpha_1 . W} \tag{3.4}$$

$$Sd = \frac{\Delta_r}{\Gamma_1 . \phi_{1,r}} \quad (3.5)$$

where W : total weight of building (kN)

V : base shear (kN)

Δ_r : roof displacement (m)

α_1 : modal mass coefficient for the fundamental mode

Γ_1 : modal participation factor for the fundamental mode

$\phi_{1,r}$: amplitude of first mode at roof level

Sa : spectral acceleration (m/s^2)

Sd : spectral displacement (m)

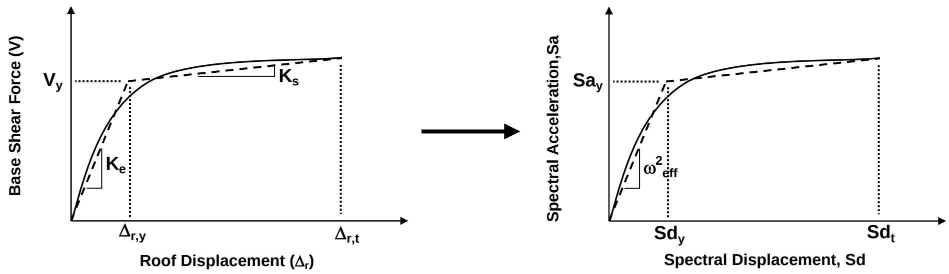

Figure 3.9 Conversion of Capacity Curve to Capacity Spectrum

In the final stage, the ω_{eff}^2 of equivalent SDOF system is determined from the initial slope of the bi-linear capacity spectrum and the force-deformation characteristics of equivalent SDOF system are computed using Eqn.s 3.6, 3.7 and 3.8:

$$M^* = \alpha_1 . M \quad (3.6)$$

$$K^* = \omega_{eff}^2 . M^* \quad (3.7)$$

$$F_y = V_y = Sa_y . M^* \quad (3.8)$$

where M : mass of the building (t)

M^* : effective mass of SDOF (t)

K^* : effective stiffness of SDOF (kN/m)

ω_{eff} : effective frequency of SDOF (s^{-1})

Sa_y : yield spectral acceleration (m/s^2)

F_y : yield force (kN)

V_y : yield base shear (kN)

The force-displacement relationship of SDOF system can then be represented as shown in Figure 3.10, where α is the ratio of post-yield stiffness (K_s) of bi-linearized capacity curve to the elastic stiffness of capacity curve (K_e). Utilizing the force-displacement relationship of the equivalent SDOF system, a nonlinear dynamic analysis is performed to obtain the inelastic displacement demand of the equivalent SDOF system. The displacement demand is later converted to global displacement by multiplying the estimated spectral displacement demand of the equivalent SDOF system with the first mode participation factor at the roof level.

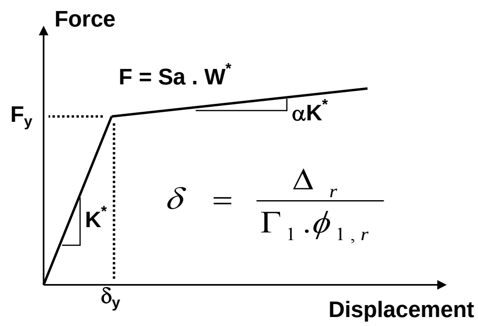

Figure 3.10 Force-Displacement Relationship of Equivalent SDOF System (ATC-40 [3])

3.5.2 Idealization of Pushover Curves

The global behavior of a structure obtained from pushover analysis can only be represented by simplified force-deformation models in typical softwares such as OpenSees [15] and NONLIN [14], since the basic hysteretic models that are implemented in the simplified nonlinear dynamic analyses require the idealized force-deformation definitions. As mentioned earlier, there are several alternatives and judgments in the idealization of capacity curves. Amongst these common alternatives, ATC, FEMA and 75%V_y [2] were employed to idealize the pushover curve of each frame. Apart from these three, since OpenSees allowed modeling the pushover curve more precisely by multi-linear segments, a fourth method called MULTI was applied to fully describe the global behavior (nonlinear static response) of the structure.

In the MULTI method, the original curve of each MDOF system was approximated using as many linear segments as chosen (generally 10-15 segments) to fully describe the non-degrading load-deformation envelope curve of the system. The properties of this multi-linear curve were then used to model a parallel spring system that was composed of many elastic perfectly-plastic springs. That is; the stiffnesses of elastic perfectly-plastic springs were tuned to obtain the stiffness equal to the one of the global curve. The parallel spring system was then modeled in OpenSees using *Parallel* material definition that combined *ElasticPP* material definitions equal in number of multi-linear segments. Considering the system as a whole, the requirement of equal area under the curves was automatically satisfied, since an almost exact force-deformation relationship with respect to the original curve was obtained by this method as illustrated in Figure 3.11.

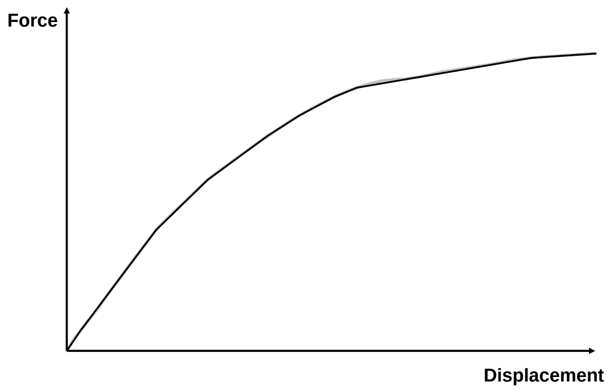

Figure 3.11 MULTI Idealization Method

In the ATC bi-linearization method, the pushover curve was approximated using a bi-linear model as described in ATC-40 [3]. The slope of the elastic portion of this bi-linear model was defined as equal to the initial stiffness of the MDOF curve and the nonlinear portion was defined as the line between the yield point and the ultimate point defined at 2.5% global drift considered as the drift capacity of the frames employed. The equal energy rule was satisfied by equating the areas under the original and the idealized curves. A sample bi-linear model of this type is depicted in Figure 3.12.

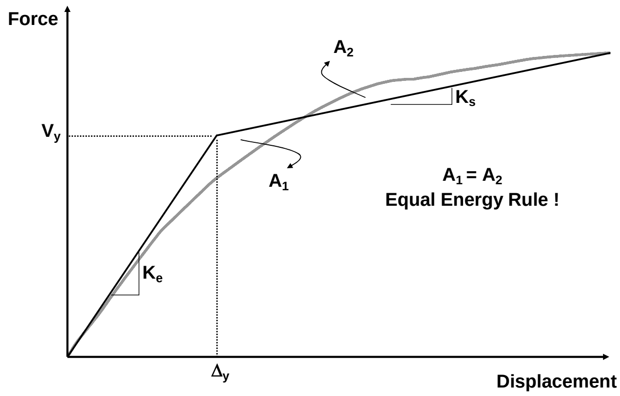

Figure 3.12 ATC Idealization Method

In the FEMA method, the elastic segment was set through an iterative process to intersect the original capacity curve at 60% of the approximate yield strength value. The nonlinear portion was defined similar to the ATC method and the equal energy rule was fulfilled through equating the areas under the curves as given in Figure 3.13.

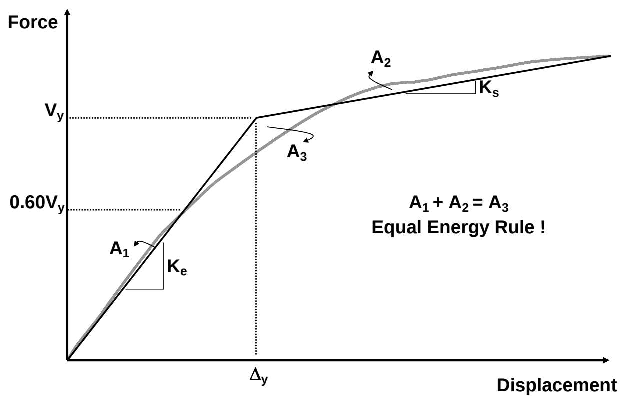

Figure 3.13 FEMA Idealization Method

In the 75%V_y method, a similar procedure to FEMA method was followed in the linearization of the original curve. However, this time, the idealized curve was set to intersect the original curve at the 75% of the approximate yield strength as shown in Figure 3.14.

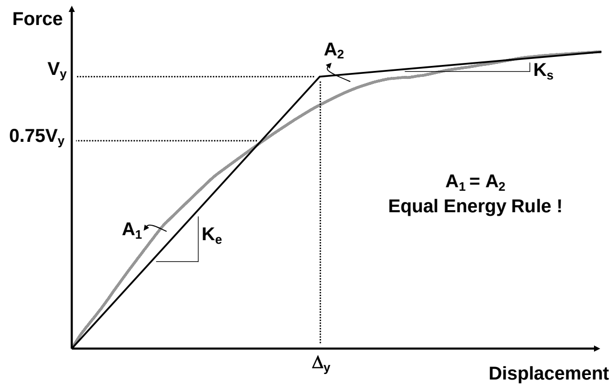

Figure 3.14 75%V_y Idealization Method

Common to all idealization methods, an assumption was made throughout idealizations. According to ATC-40 and FEMA-356, when a capacity curve is idealized, the ultimate displacement should be defined as the probable target displacement and the idealization with equal area rule should be applied only to this limited portion of the original curve. The logic behind this application is that the energy absorbed and dissipated by the structure during an earthquake would better be approximated by using this procedure. Since the application of this theoretical step to this study would have made the calculations more complex, the individual and iterative idealization process for each frame and each ground motion was not conducted. For the sake of simplicity, the idealization was made once for each frame using the whole curve defined at a drift limit of 2.5% that reflected the capacity of each frame.

Using the guidelines above, the capacity curve of each frame was idealized according to the four methods. Figures 3.15-3.17 presents the comparative idealizations of each frame with details. The yield base shear force and yield displacement with other corresponding parameters are summarized in Table 3.2. Note that, since MULTI method does not have a logical definition of yield, an assumption was made at this step to define the yield displacement and strength of MULTI idealizations equal to the ones of ATC method due to the fact that they have the same elastic stiffnesses.

Considering the comparative figures presented, it can generally be said that the ATC bi-linearization method provided with more rigid representation of the system due to the use of initial stiffness of the corresponding system causing earlier yielding of the system and a higher value of hardening ratio. 75%V_y method, on the other hand, yielded more flexible models of the original system with the lowest value of post-elastic stiffness. FEMA method often remained close to 75%V_y, however, represented the system with a more rigid one. In contrast to this general view, for the capacity curves that are close to bi-linear curves, some of the approximation methods would yield similar idealized curves.

Table 3.2 Properties of Idealized Pushover Curves

Frame	**Approximation Method**	**Yield Base Shear Force (kN)**	**Yield Roof Displacement (m)**	**Yield Base Shear Coefficient**	**Yield Average Interstory Drift Ratio (%)**	**Post-Yield Slope (%)**	**Ductility @ 2.5% drift**
F2S2B	MULTI	882.0	0.0550	0.327	0.69	14.2	3.60
	ATC	882.0	0.0550	0.327	0.69	14.2	3.60
	FEMA	964.8	0.0697	0.357	0.88	13.7	2.84
	75%Vy	1110.0	0.0937	0.411	1.18	8.1	2.11
F2S2B2	MULTI	1087.3	0.0396	0.805	0.66	14.4	3.79
	ATC	1087.3	0.0396	0.805	0.66	14.4	3.79
	FEMA	1129.7	0.0430	0.837	0.72	13.5	3.49
	75%Vy	1145.3	0.0443	0.848	0.74	13.1	3.39
F3S2B	MULTI	1029.5	0.0592	0.463	0.66	14.7	3.80
	ATC	1029.5	0.0592	0.463	0.66	14.7	3.80
	FEMA	1076.2	0.0653	0.484	0.73	13.9	3.45
	75%Vy	1108.2	0.0697	0.499	0.77	13.1	3.23
F5S2B	MULTI	721.0	0.0702	0.282	0.47	1.8	5.34
	ATC	721.0	0.0702	0.282	0.47	1.8	5.34
	FEMA	774.7	0.0957	0.303	0.64	0.1	3.92
	75%Vy	773.6	0.0987	0.303	0.66	0.1	3.80
F5S4B	MULTI	3003.0	0.1244	0.304	0.63	6.8	3.98
	ATC	3003.0	0.1244	0.304	0.63	6.8	3.98
	FEMA	3228.9	0.1557	0.327	0.79	5.5	3.18
	75%Vy	3255.3	0.1593	0.329	0.80	5.2	3.11
F5S7B	MULTI	2745.4	0.0695	0.364	0.49	3.4	5.11
	ATC	2745.4	0.0695	0.364	0.49	3.4	5.11
	FEMA	2988.4	0.0972	0.396	0.68	1.8	3.65
	75%Vy	3058.9	0.1052	0.405	0.74	1.0	3.37
F8S3B	MULTI	3396.0	0.1508	0.191	0.42	4.7	5.26
	ATC	3396.0	0.1508	0.191	0.42	4.7	5.26
	FEMA	3639.3	0.1985	0.204	0.56	4.0	3.99
	75%Vy	3661.7	0.2029	0.206	0.57	3.9	3.91

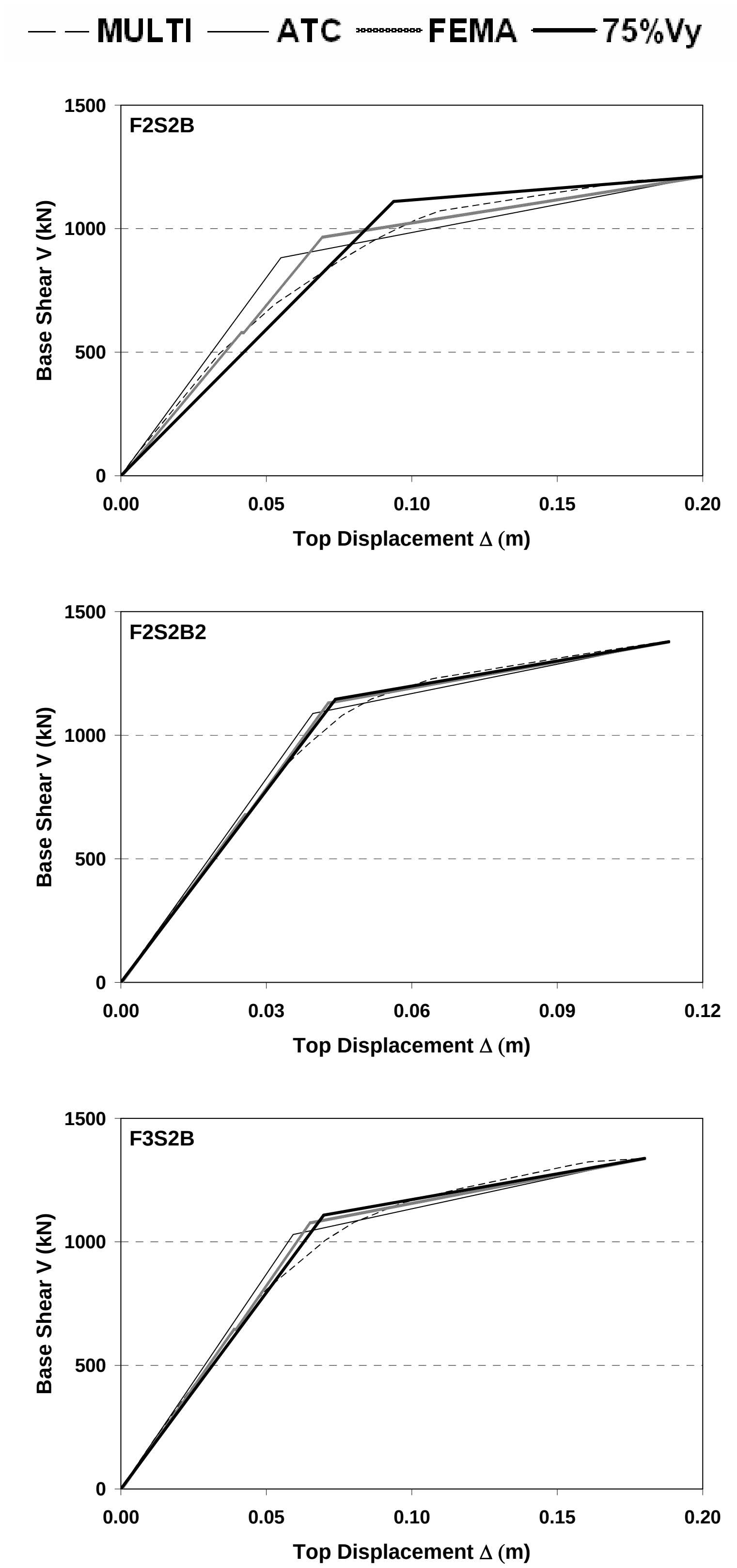

Figure 3.15 Comparative Idealizations of Pushover Curves for Frames 'F2S2B', 'F2S2B2' and 'F3S2B'

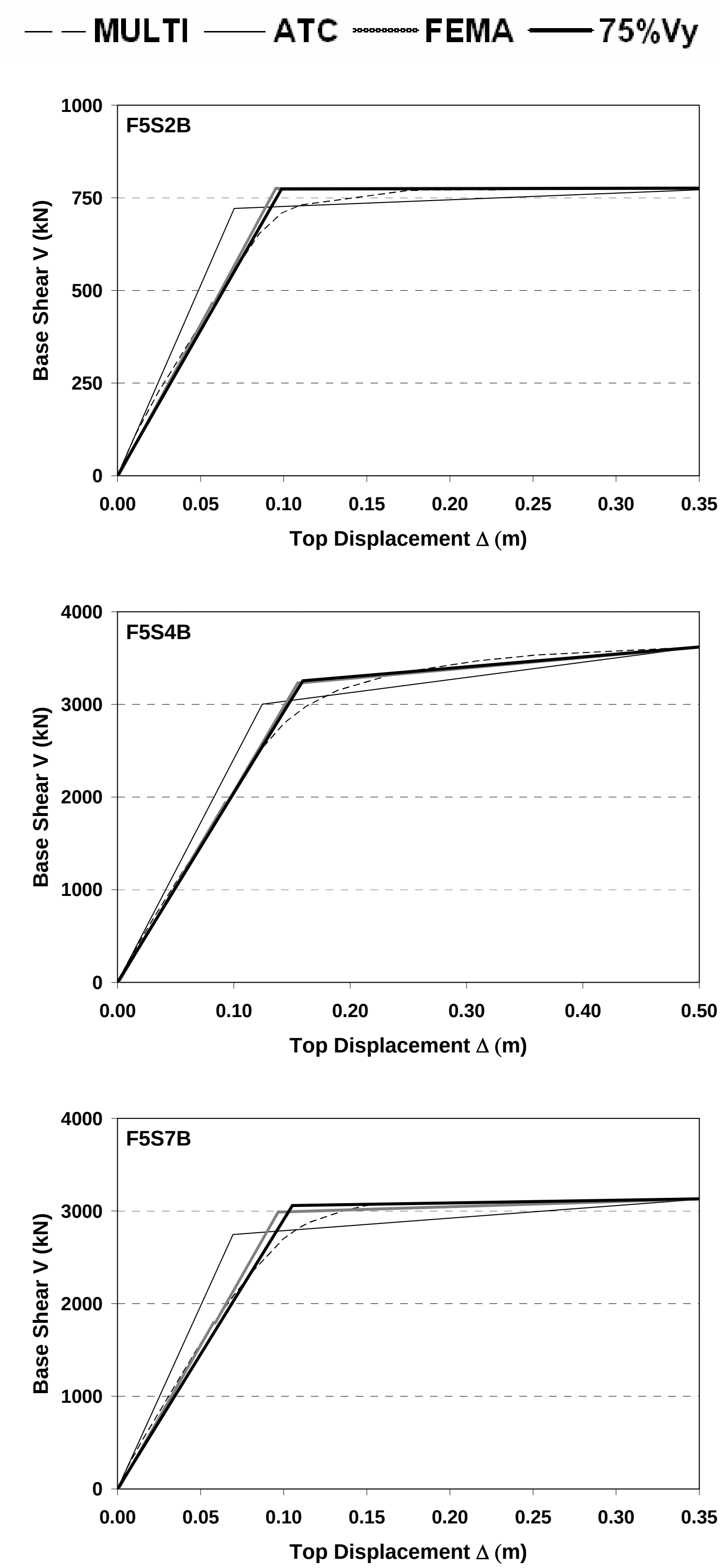

Figure 3.16 Comparative Idealizations of Pushover Curves for Frames 'F5S2B', 'F5S4B' and 'F5S7B'

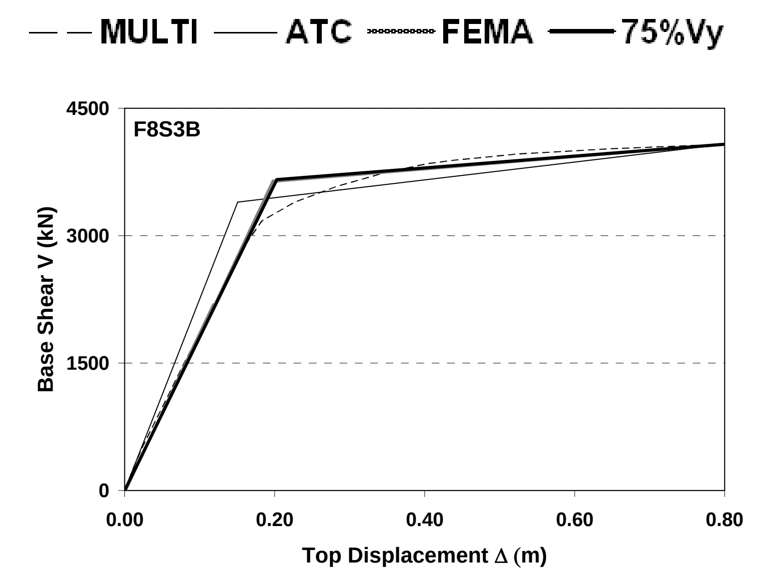

Figure 3.17 Comparative Idealizations of Pushover Curves for Frame 'F8S3B'

3.5.3 Equivalent SDOF Analyses Results

The equivalent SDOF systems of the idealized capacity curves of each frame were formed on the basis of first mode behavior using the theoretical principles summarized previously. The properties of these equivalent systems were later assigned to the system shown below in Figure 3.18. As previously described, the spring force-deformation relationship for the MULTI idealization method was formed using Parallel and ElasticPP material definitions of OpenSees. For the other three idealization methods, Steel01 material definition was used to represent the idealized behavior of the structures. Figure 3.19 shows sample hysteresis loops for both multi- and bi-linear models. The reason for using simple bi-linear model with kinematic hardening and without defining stiffness or strength degradation was that it was not aimed in this study to investigate the effects of degradation on SDOF response. In contrast, the study was intended to evaluate the effects of idealization methods on simple models without introducing further complexities.

Using the equivalent SDOF system properties given in Table 3.3 and taking the Rayleigh damping coefficient of the SDOF system equal to the coefficient of corresponding MDOF system, simplified nonlinear dynamic analyses were conducted again employing the same strong-motion database and utilizing OpenSees. For the equivalent SDOF system properties, note that only the approximate bi-linear properties are given, since MULTI method's properties were complex to present in a single table.

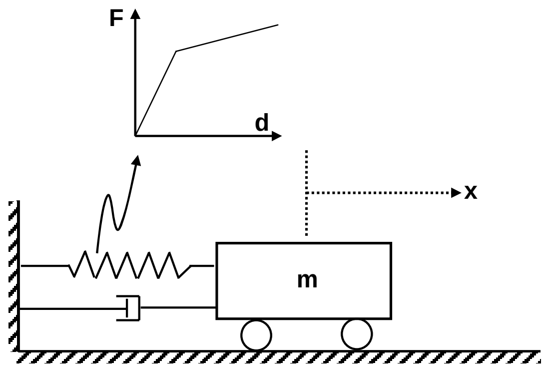

Figure 3.18 Equivalent SDOF System

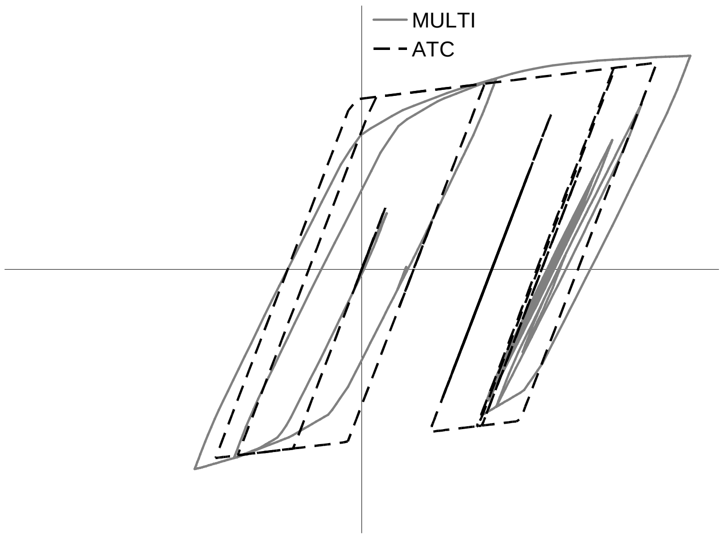

Figure 3.19 Sample Hysteresis Loops

Computing the maximum displacement demand of the SDOF system under each ground motion from the nonlinear analysis results, the maximum top displacement demand of the corresponding MDOF system was obtained. Later, the approximate seismic response values at the target displacements were obtained by using the results of pushover analyses. In addition to the nonlinear dynamic analyses, linear elastic dynamic analyses using the elastic stiffnesses of idealizations were conducted for each frame to compute the strength reduction factors, R. The strength reduction factors for each idealization method were calculated according to Eqn. 3.9:

$$R = \frac{V_{elastic}}{V_{yield}} \qquad \text{R<1: Elastic case} \qquad (3.9)$$

where $V_{elastic}$ denotes the maximum base shear force obtained from the linear elastic dynamic analysis of a system using the elastic stiffness definition of the idealization method used and V_{yield} stands for the yield strength of the corresponding method of idealization of that frame.

In addition to the strength reduction factors, the ductility levels imposed on the frames due to the seismic excitations were also computed for each idealization method using Eqn. 3.10:

$$\mu = \frac{\Delta}{\Delta_y} \qquad \mu\text{<1: Elastic case} \qquad (3.10)$$

where Δ denotes the maximum top displacement demand of the frame under a strong motion and Δ_y represents the yield displacement of the frame with respect to the method it has been idealized.

The results obtained from the approximate analyses of the frames are given in Appendix A.3.

Table 3.3 Properties of the Equivalent SDOF Systems

Frame	Idealization Method	Teff (s)	Sa_y (g)	Sd_y (m)	F_y (kN)	K* (kN/m)	α (%)
F2S2B	ATC	0.642	0.401	0.041	882.0	21475.7	14.16
	FEMA	0.691	0.439	0.052	964.8	18537.5	13.65
	75%Vy	0.747	0.505	0.070	1110.0	15864.9	8.05
F2S2B2	ATC	0.347	0.988	0.030	1087.3	36766.9	14.43
	FEMA	0.355	1.027	0.032	1129.7	35178.7	13.51
	75%Vy	0.358	1.041	0.033	1145.3	34619.6	13.09
F3S2B	ATC	0.528	0.603	0.042	1029.5	24631.8	14.69
	FEMA	0.543	0.631	0.046	1076.2	23333.3	13.87
	75%Vy	0.552	0.649	0.049	1108.2	22510.0	13.12
F5S2B	ATC	0.784	0.356	0.054	721.0	13278.6	1.76
	FEMA	0.882	0.382	0.074	774.7	10470.1	0.06
	75%Vy	0.897	0.382	0.076	773.6	10136.5	0.12
F5S4B	ATC	0.969	0.392	0.091	3003.0	32871.7	6.80
	FEMA	1.045	0.421	0.114	3228.9	28239.2	5.47
	75%Vy	1.053	0.424	0.117	3255.3	27826.3	5.24
F5S7B	ATC	0.694	0.452	0.054	2745.4	50766.4	3.44
	FEMA	0.786	0.492	0.076	2988.4	39511.5	1.83
	75%Vy	0.808	0.504	0.082	3058.9	37368.7	1.02
F8S3B	ATC	1.253	0.270	0.106	3396.0	32196.7	4.66
	FEMA	1.389	0.290	0.139	3639.3	26212.2	3.96
	75%Vy	1.400	0.291	0.142	3661.7	25801.2	3.85

3.6 COMPARISON OF RESULTS

The seismic demands in terms of maximum roof displacement, maximum base shear and maximum inter-story drift ratio that were obtained from the equivalent SDOF analyses were compared with the 'exact' results that were obtained from the nonlinear time history analyses of MDOF systems. In the comparison, as an error indicator for each idealization method, the approximate results were divided by the 'exact' results as shown in Eqn. 3.11:

$$\text{Ratio} = \frac{\text{Result}_{\text{approximate}}}{\text{Result}_{\text{exact}}} \tag{3.11}$$

where '$\text{Result}_{\text{approximate}}$' denotes the approximate result obtained from one of the idealization methods ; MULTI, ATC, FEMA and 75%V_y, in terms of maximum top displacement, maximum inter-story drift ratio and maximum base shear whereas '$\text{Result}_{\text{exact}}$' indicates the corresponding 'exact' result.

In the comparisons of maximum inter-story drift ratio values, the location of maximum drift ratio was not considered and only critical drift ratio throughout the structure was compared. The selection of maximum inter-story drift ratio throughout the structure would be a better indicator in performance-based assessment of regular moment resisting systems.

Apart from the comparisons of the approximate results obtained for each idealization method with respect to 'exact' results of nonlinear time history analyses, the results of the approximate procedures; ATC, FEMA and 75%V_y, were compared with the results of MULTI method. This comparison was made because of the assumption that since the global behavior of a structure is better represented by a capacity curve rather than individual dynamic analyses whose results are hard to interpret and multi-linear representation of the capacity curve completely reflects the global behavior of a structure, it would be better to compare the common idealization methods with respect to multi-linear method. The assumption here is particularly valid for non-pulse type ground motions which generally constitute the current ground motion database employed. The comparison was made similar to Eqn. 3.11. However, for the approximate results only the ones of ATC, FEMA and 75%V_y were used and as the denominator, MULTI method's results were used instead of 'exact' results.

The comparisons made with respect to both 'exact' and 'MULTI' results for the selected frames are given in tables which can be found in Appendix A.4. The interpretations of the comparisons will be presented in the next chapter of the thesis.

CHAPTER 4

INTERPRETATION OF RESULTS

4.1 INTRODUCTION

Using the results obtained from nonlinear time history analyses of MDOF systems and simplified time history analyses using equivalent SDOF systems obtained through idealization of the capacity curve of each frame according to the alternatives presented, the influence of idealizations on seismic response of structures were investigated.

Comparisons of the approximate results with respect to ‘exact’ results for maximum top displacement, maximum inter-story drift ratio and maximum base shear were studied first along with the correlation studies evaluating the accuracy of approximations with respect to nonlinear time history analyses. Secondly, to investigate the effects of approximations, the average of ratios, specified as error indicators in the previous chapter, were summarized graphically at various levels of global drift. As the final stage, the trends and dependencies of error indicators on ductility, strength reduction factor and period were evaluated. The details about the statistical studies and the overall interpretation of results are presented in the next sections.

4.2 INTERPRETATIONS WITH RESPECT TO ‘EXACT’ RESULTS

4.2.1 Correlation Studies

Approximate maximum top displacement, maximum inter-story drift ratio and maximum base shear demands computed by the simplified analyses were first compared with ‘exact’ results to investigate the correlation between each other. The comparisons are presented as scatter diagrams which show the perfect correlation as the diagonal line. In addition to the graphical comparisons, statistical studies were also conducted to quantify the correlation. The ‘coefficient of correlation’, ρ, which was used to quantify the correlation between the results of each approximation and the 'exact' results, were calculated according to Eqn. 4.1 [1]:

$$\rho = \frac{1}{n-1} \cdot \frac{\sum_{i=1}^{n} (x_i - \bar{x}) \cdot (y_i - \bar{y})}{s_x \cdot s_y} \tag{4.1}$$

where $\bar{x}$, $\bar{y}$, s_x and s_y are, respectively, the sample means and sample standard deviation of X and Y.

The comparison of maximum top displacement results for each idealization method with respect to 'exact' results for frame 'F2S2B' are illustrated in Figure 4.1 on which the correlation coefficient values are also indicated. For the other frames, graphical comparisons can be found in Appendix A.5.

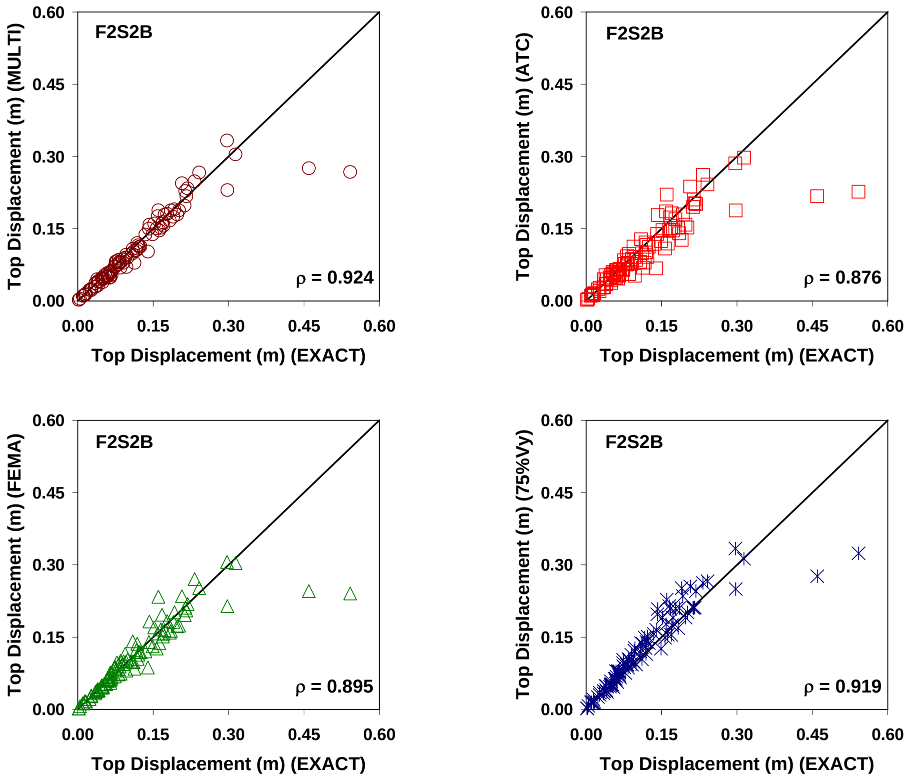

Figure 4.1 Comparison of Approximate Results with respect to 'EXACT' Values of Maximum Top Displacement for Frame 'F2S2B'

Considering the maximum top displacement demand comparisons as depicted in Figure 4.1 and Figures A.5.2-A.5.7, all approximations captured 'exact' behavior very well up to the yield displacement of each frame. After yield of the systems, however, dispersions increased. Both under-estimations and over-estimations of the methods were observed after these points. ATC method gave the most dispersed results and it generally under-estimated maximum displacement demands except for frame ‘F5S2B’. FEMA and 75%V_y methods usually showed the same trend in predicting the displacement demands. Excluding frame ‘F5S2B’ which demonstrated large variations in results, as a general tendency both methods over-estimated the demands after yield. On the other hand, MULTI method gave the least scattered results which were also supported by the correlation coefficient calculations. Based on the correlation coefficient computations as summarized in Table 4.1, all methods could be said to have strong correlation with ‘exact’ results with the exception of ATC approximation which mostly gave the lowest coefficient of correlation values.

Table 4.1 Coefficient of Correlation Values of Approximation Alternatives at Predicting Maximum Top Displacement Demands

FRAME	MULTI	ATC	FEMA	75%V_y
F2S2B	0.924	0.876	0.895	0.919
F2S2B2	0.971	0.954	0.967	0.971
F3S2B	0.978	0.961	0.961	0.961
F5S2B	0.938	0.910	0.866	0.877
F5S4B	0.979	0.942	0.964	0.965
F5S7B	0.992	0.890	0.975	0.980
F8S3B	0.972	0.939	0.957	0.961
Overall Mean	0.965	0.925	0.941	0.948

Using the similar graphical comparisons for maximum inter-story drift ratio that are illustrated in Figure 4.2 for frame ‘F2S2B’ and Figures A.5.9-A.5.14 for other frames, all methods presented perfect correlation in low maximum inter-story drift ratio values corresponding to the elastic range. Nevertheless, at high drift ratios, the performance of idealization methods at capturing ‘exact’ behavior decreased and the methods showed a general tendency to under-estimate drift demands. In contrast to this general tendency, there were some cases in which the methods slightly over-estimated the results. Based on the quantified results of correlation as given in Table 4.2, except for frames ‘F2S2B’ and

‘F5S2B’ for which low correlation coefficient values were observed, all methods showed strong correlation; ATC method generally yielding the lowest ones.

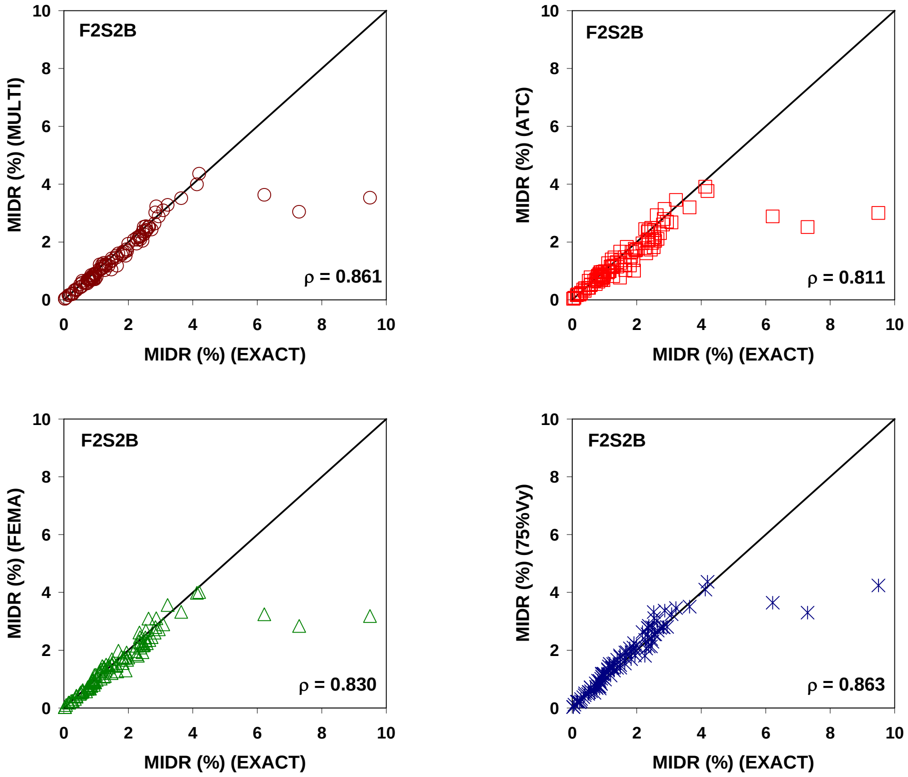

Figure 4.2 Comparison of Approximate Results with respect to ‘EXACT’ Values of Maximum Inter-Story Drift Ratio for Frame ‘F2S2B’

Table 4.2 Coefficient of Correlation Values of Approximation Alternatives at Predicting Maximum Inter-Story Drift Ratio Demands

FRAME	MULTI	ATC	FEMA	75%V_y
F2S2B	0.861	0.811	0.830	0.863
F2S2B2	0.973	0.959	0.970	0.973
F3S2B	0.980	0.964	0.964	0.966
F5S2B	0.883	0.840	0.811	0.817
F5S4B	0.981	0.946	0.970	0.971
F5S7B	0.926	0.756	0.906	0.927
F8S3B	0.951	0.938	0.943	0.946
Overall Mean	0.936	0.888	0.914	0.923

The graphical comparisons for maximum base shear values are depicted in Figure 4.3 and Figures A.5.16-A.5.21. All idealization methods performed well on the average in the elastic range. In yield base shear range of frames, the approximate results were dispersed widely pointing out the poor performance of the methods in these regions. The general behavior after yielding of systems could be expressed as under-estimation of maximum base shear values. Among the alternatives, ATC method showed the most scattered results which was also supported by the correlation studies as summarized in Table 4.3. The methods MULTI, FEMA and 75%V_y showed high correlation with the 'exact' results considering the whole data. In addition, the case of dispersed results showing under-estimations as well as over-estimations for mid-rise buildings changed into the case of definite under-estimations for the relatively high rise frame indicating the significance of higher mode effects.

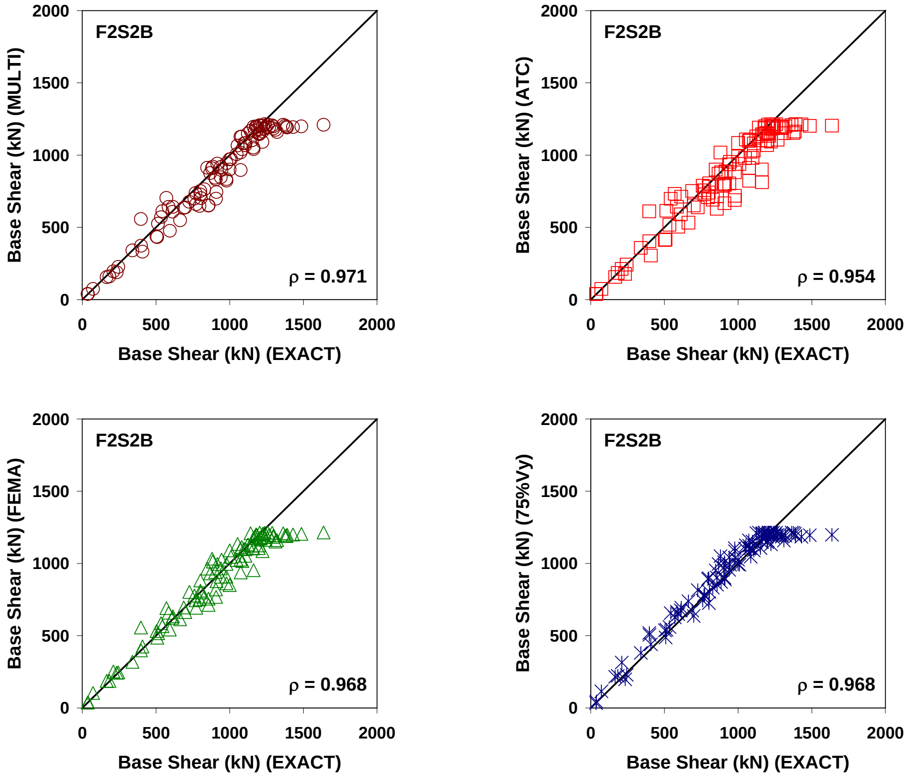

Figure 4.3 Comparison of Approximate Results with respect to 'EXACT' Values of Maximum Base Shear for Frame 'F2S2B'

Table 4.3 Coefficient of Correlation Values of Approximation Alternatives at Predicting Maximum Base Shear Demands

FRAME	MULTI	ATC	FEMA	75%V_y
F2S2B	0.971	0.954	0.968	0.968
F2S2B2	0.980	0.965	0.978	0.982
F3S2B	0.976	0.962	0.968	0.973
F5S2B	0.977	0.941	0.982	0.980
F5S4B	0.970	0.951	0.971	0.972
F5S7B	0.979	0.934	0.982	0.982
F8S3B	0.956	0.937	0.955	0.956
Overall Mean	0.973	0.949	0.972	0.973

4.2.2 Comparison of Methods at Various Levels of Global Drift

Apart from the correlation studies, the approximation methods were also compared at various levels of global drift. The selection of drift level instead of ductility level was based on the fact that each idealization method has its own yield displacement definition and thus causing different ductility values. On the other hand, by using drift based comparisons, it would be easier to figure out the unbiased error level in the prediction of the demand parameter sought at the level of global drift considered.

Using the comparison results in terms of ratios as error indicators previously given, the results were clustered at each 0.5% global drift increments for each approximation method. That is, for 1% global drift, the results in the range between 0.75% and 1.25% global drift were collected. If the number of data collected from this range was less than 3, the data was discarded. For each method, mean, standard deviation, minimum and maximum values were calculated using the data within the above pre-defined drift levels. Later, for every frame, these statistical results were expressed as minimum, maximum, mean, mean minus/plus one standard deviation values at the specified global drift levels.

Figures 4.4 to 4.9 present the statistical features of the error indicators calculated based on the approximations employed. In these figures, solid boxes show the mean value (center line of the box) and plus/minus one standard deviation (upper and lower edges of the box). Vertical lines passing through the center of the boxes depict the upper and lower limits of the values that are maximum and minimum values. In certain cases, due to rigidity and strength of the individual frames, results could not be calculated at high drift ratios.

Considering the prediction capability of approximations in terms of maximum displacement demand as given in Figure 4.4 and Figures A.6.2-A.6.7, it was observed that the results were highly affected by individual ground motions since some methods yielded even 60% under-estimations and 70% over-estimations for some of the frames. Nonetheless, as a general behavior, the mean error in computing the displacement demand remained around 20%. Up to average yield drift ratios which are in the range of 0.4 to 1.2, MULTI and ATC methods under-estimated the 'exact' displacement as much as 15%. In contrast, FEMA and 75%V_y methods usually remained close to exact prediction line with the latter one giving the highest displacement demand. After the yield global drift levels, the general trend to under-estimate or to over-estimate was observed to be unclear, but the dispersion of each method at high drift levels was noticed to be increased. MULTI method commonly showed little dispersion whereas ATC method indicated the most scattered results. Having higher standard deviations as opposed to MULTI method, FEMA method globally gave very close results with respect to the 'exact' maximum top displacement demands. Hence, when the roof displacement demand predictions are of concern, FEMA method was observed to be the most accurate one among the alternatives employed.

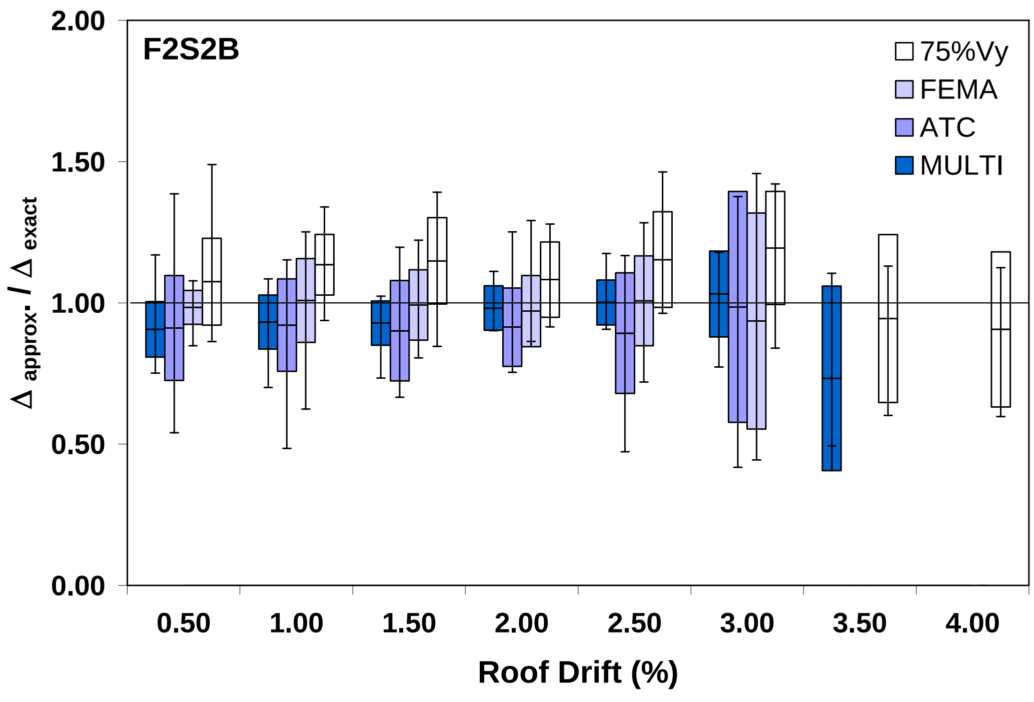

Figure 4.4 Comparison of Approximations with respect to 'EXACT' Values of Maximum Top Displacement at Specified Global Roof Drifts for Frame 'F2S2B'

Similar to maximum roof displacement predictions, the errors indicating the ratios of maximum inter-story drift were also summarized as previously described. As illustrated through Figure 4.5 and Figures A.6.9-A.6.14, both lower and upper limits for mean errors at indicated drift levels were around 25%. However, in some methods, the errors approached to 85% with both under-estimations and over-estimations indicating that the results were highly affected from the ground motion characteristics. MULTI and ATC methods gave very close results and generally under-estimated the response. On the contrary, FEMA and 75%V_y methods predicted the critical inter-story drift demands in a better sense with relatively small under-estimations as well as slightly conservative results for some cases. MULTI method again usually showed the least dispersion in results with 75%V_y being the second.

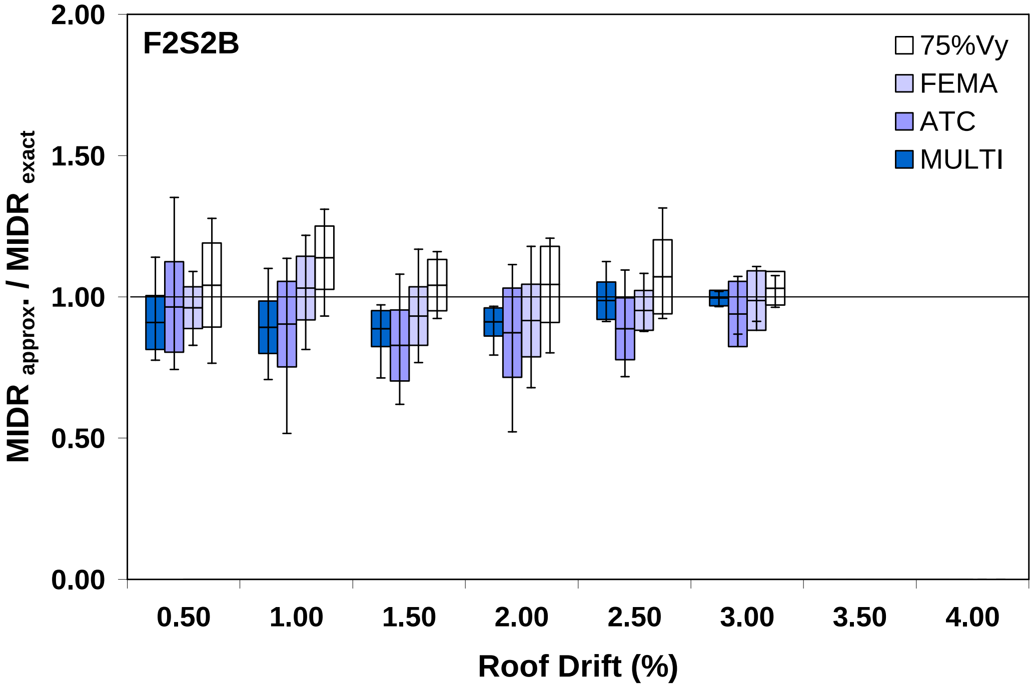

Figure 4.5 Comparison of Approximations with respect to 'EXACT' Values of Maximum Inter-Story Drift Ratio at Specified Global Roof Drifts for Frame 'F2S2B'

Similarly, the effects of approximation methods on maximum base shear predictions are also summarized in Figure 4.6 and Figures A.6.16-A.6.21. The comparisons summarized indicated that up to yield drift levels for low- to mid-rise structures, the under-estimation in mean errors was limited by 10% for MULTI and ATC methods. FEMA and 75%V_y yielded even better force demand predictions by giving higher values of base shear. These results can be attributed to higher yield base shear force values attained through FEMA and 75%V_y. Additionally, the expectation that the shear force predictions based on approximate methods yield under-estimations due to the capacity curves representing lower-bound of exact values is also revealed in these plots. However, considering the under-estimations and over-estimations computed up to 40% and 50%, respectively, the dispersions for all methods could be said to be high in elastic defined regions. Beyond these regions, general behavior of approximation methods was to slightly under-estimate the demand, but the dispersions diminished to comparatively small values. For the relatively high rise building, on the other hand, the under-estimation in mean errors were in the order of 15-20% without pointing out a single alternative that captured 'exact' behavior in a better sense. The results for this frame again indicated the presence of higher mode effects.

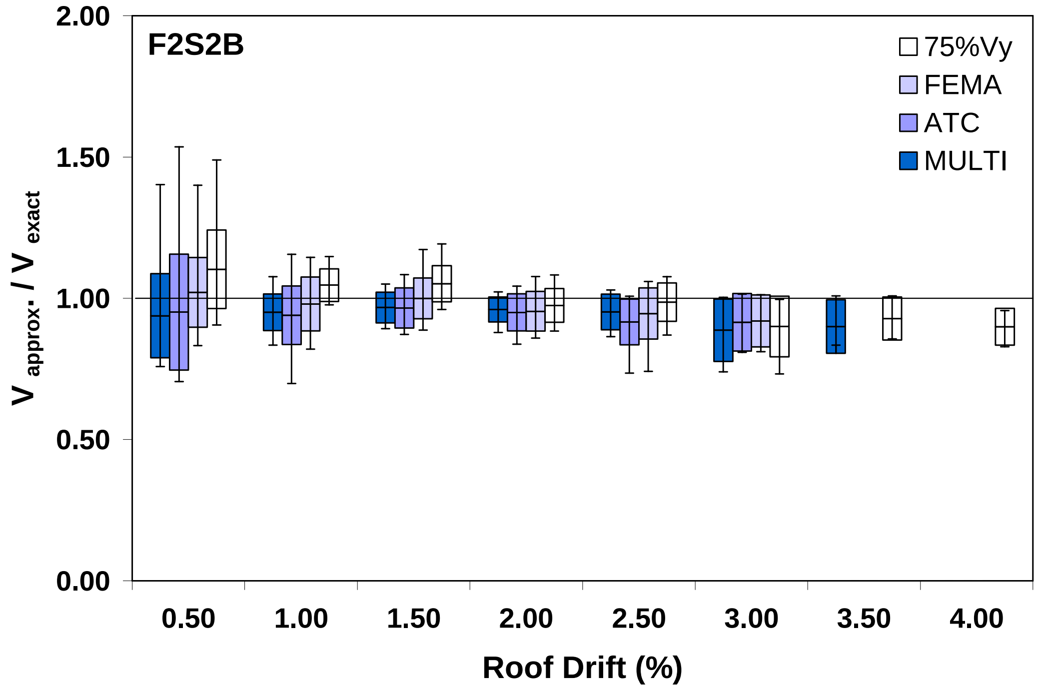

Figure 4.6 Comparison of Approximations with respect to 'EXACT' Values of Maximum Base Shear at Specified Global Roof Drifts for Frame 'F2S2B'

In general, ATC method showed the most dispersion in elastic regions according to standard deviation, minimum, and maximum values. Unlike MULTI and ATC, FEMA and 75%V_y were able to capture the 'exact' base shear demands satisfactorily up to the yield of systems. After yielding, all methods gave similar results.

4.2.3 Period-wise Comparison of Methods

The results of the previous section were re-evaluated to represent the error distribution with respect to period. The mean error ratios for maximum displacement demands of each frame, as illustrated in Figure 4.7, showed that ATC and MULTI methods gave very close results and generally under-estimated 'exact' demands as much as 10%, whereas FEMA and 75%V_y, being the second couple, yielded better predictions of the roof displacement demands with conservative results in some cases. Despite the fact that the results highly vary due to record-to-record variability, it was observed that MULTI exhibited the least scatter, although it under-estimated the response at all periods. On the contrary, FEMA was observed to be the best alternative by yielding results very close to the 'exact' results with relatively small dispersion.

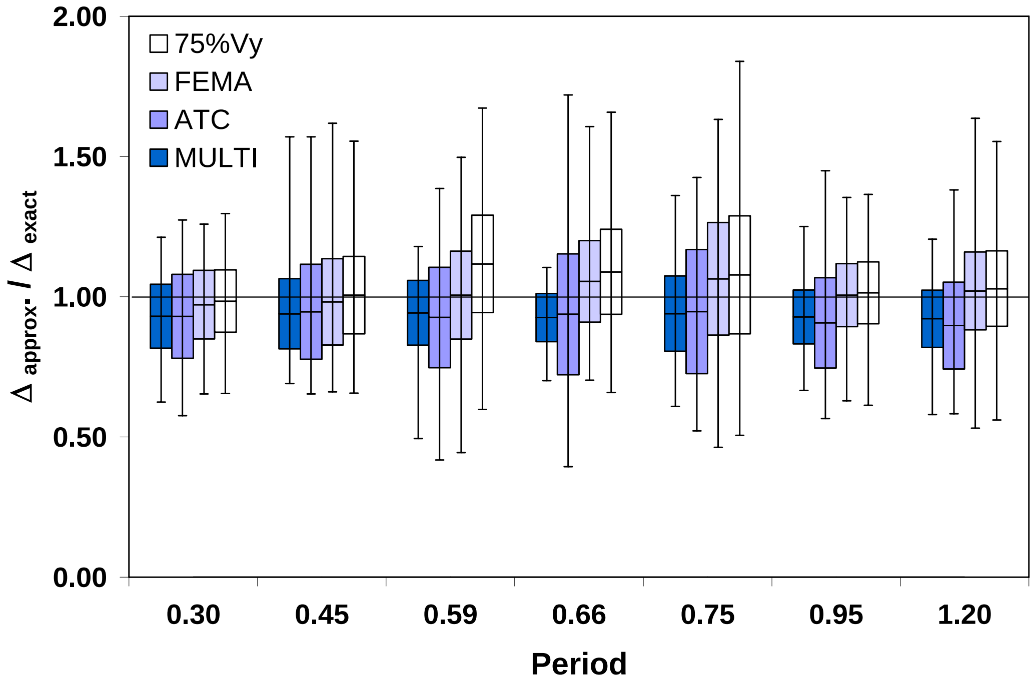

Figure 4.7 Period-wise Distribution of Comparisons for
Maximum Displacement Demands with respect to 'EXACT' Results

Along with the period-wise comparison graph, the fundamental period dependency graphs as depicted in Figure 4.9 showed that there was no clear trend between period and mean roof displacement demand prediction errors. Hence, it could be said that, on the average, the accuracy of methods at mean displacement demand estimation is not significantly affected by the period change. Additionally, the under-estimating behavior of MULTI and ATC methods were also confirmed by these graphs.

In the prediction of 'exact' maximum inter-story drifts, as depicted in Figure 4.8, MULTI and ATC methods resulted in 5-10% under-estimations for low- and mid-rise frames. Additionally, the mean errors reached 20% for the eight-story frame. Unlike these two, FEMA and 75%V_y methods generally predicted the 'exact' mean demands within 5% error. For the high rise building, in contrast, the error for these methods reached 10%. MULTI method again showed little dispersion in results, whereas the other three were similar considering the scatter of results. In spite of the relatively low dispersions, in some cases, the extreme errors were in the order of 80-85% giving both under- and over-estimated results. Regarding the mean ratios, FEMA and 75%V_y methods could be said to be the best alternatives in capturing the 'exact' drift demands.

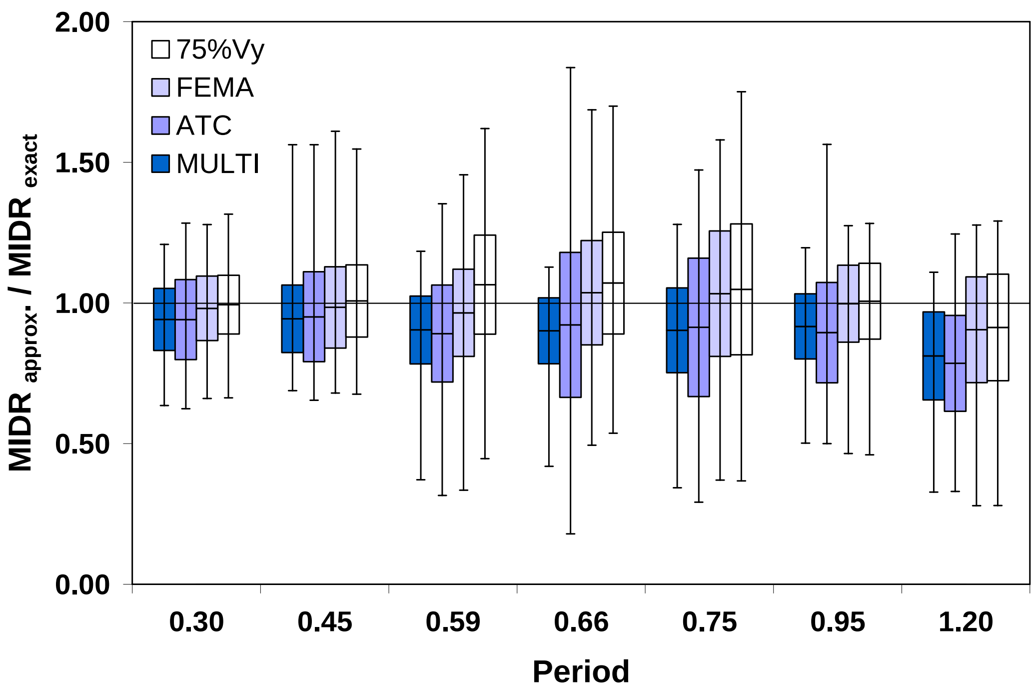

Figure 4.8 Period-wise Distribution of Comparisons for
Maximum Inter-story Drift Ratio Demands with respect to 'EXACT' Results

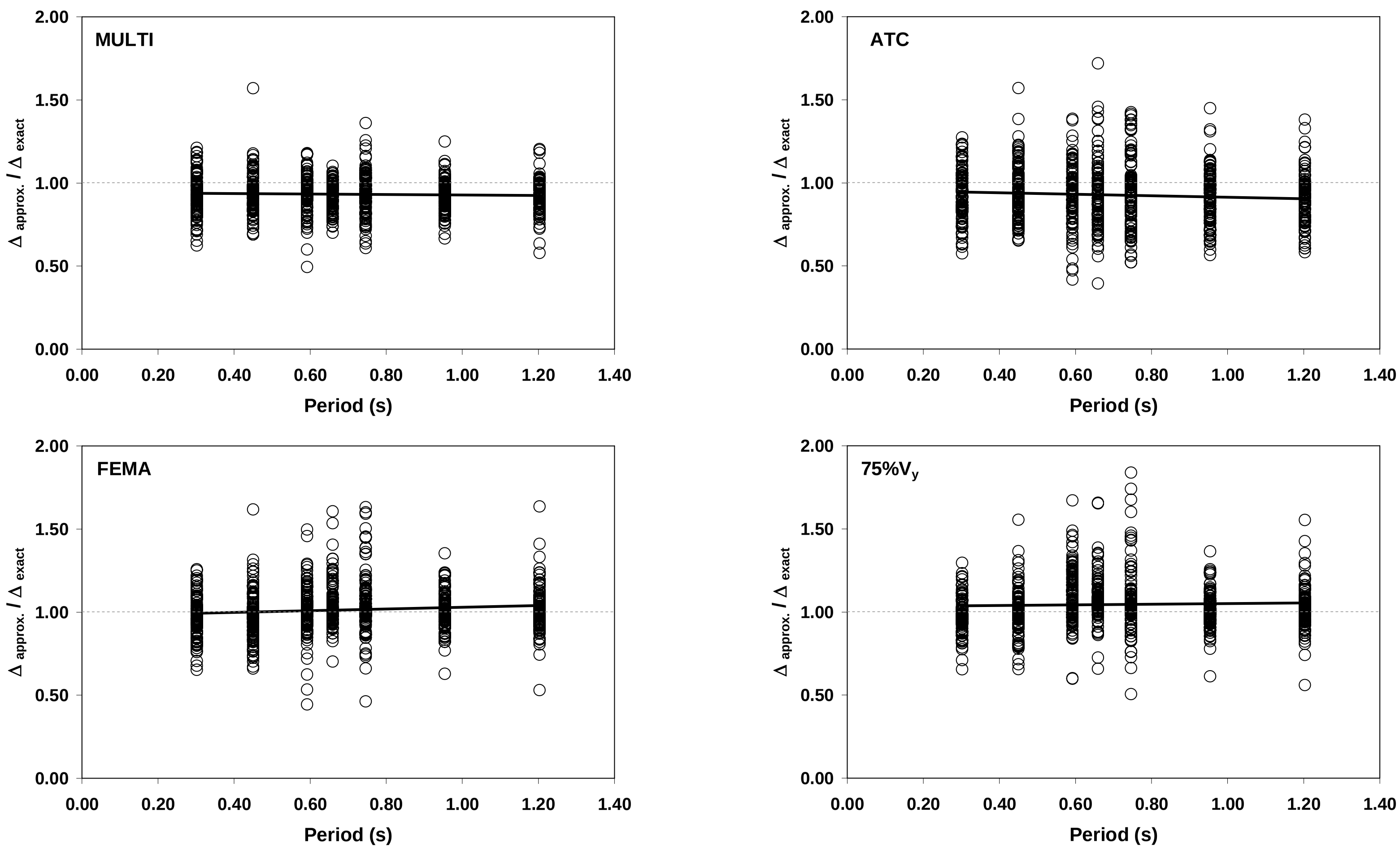

Figure 4.9 Dependency on Period (Maximum Top Displacement)

The error plots as a function of fundamental period as presented in Figure 4.11 also supported the previous findings that MULTI and ATC methods generally under-estimated the results and this under-estimation increased with increasing the period. Although similar trend was observed for the FEMA and 75%V_y methods, this was relatively insignificant.

Examination of the mean ratios presented in Figure 4.10 revealed that ATC and MULTI methods predicted the base shear demand with an under-estimation error of 10% for low- to mid-rise frames. For the frame with highest period, the mean errors reached almost 20%. The mean errors for FEMA and 75%V_y remained less than 5% generally, but for the relatively high-rise frame the average was observed to be 10%. Consequently, the last two alternatives gave closer estimations of maximum base shear demand at all cases. The deviation in results, although not significantly different from others, was smallest for the idealization method, MULTI.

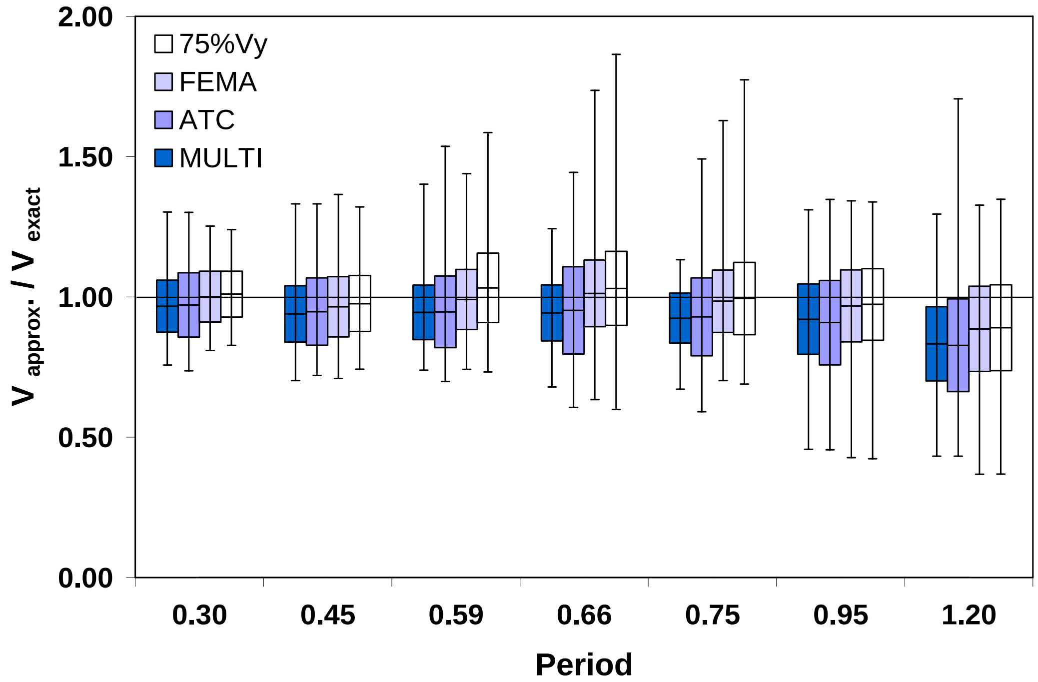

Figure 4.10 Period-wise Distribution of Comparisons for Maximum Base Shear Demands with respect to ‘EXACT’ Results

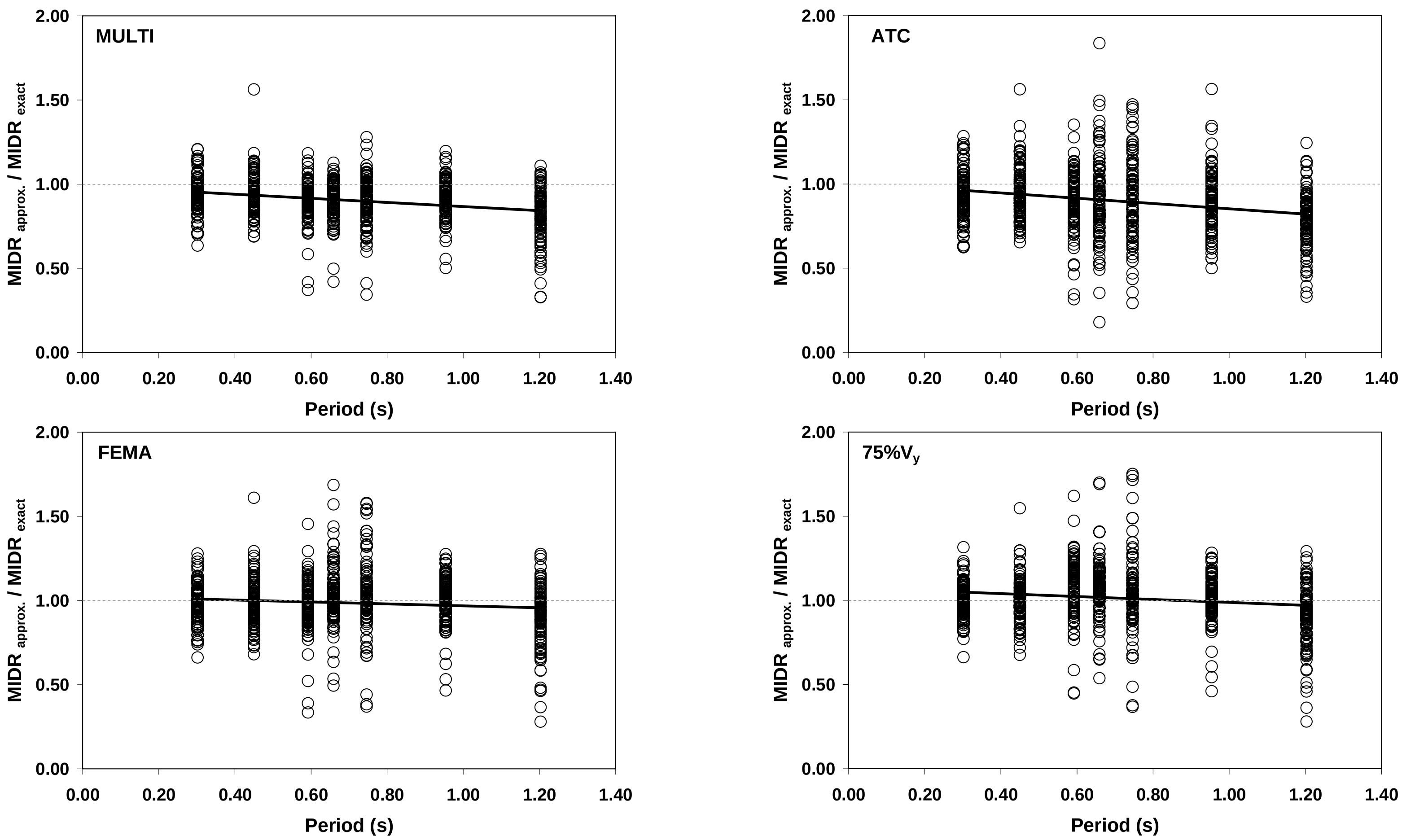

Figure 4.11 Dependency on Period (Maximum Inter-Story Drift Ratio)

Similar to the observations made for the inter story drift, the effect of period change on the prediction capability of idealization alternatives was observed to be a decrease in accuracy with increasing periods as illustrated in Figure 4.12. It was also noticed that the decrease in accuracy of MULTI and ATC methods were higher with respect to the decrease in accuracy of FEMA and 75%V_y methods. This reveals that the MULTI and ATC methods' prediction capabilities at estimating force demands are weaker at high periods.

4.2.4 Trends and Dependencies on Ductility and Strength Reduction Factor

Apart from the comparisons of methods at specified global drift levels, the likely error dependency on ductility (μ) and strength reduction factor (R) were also investigated. When seeking for dependencies on ductility and strength reduction factor, for each seismic demand parameter and each frame, all results were shown as data points and linear regression line was obtained from these data points. By using the linear trend lines, it would be possible to identify the dependencies of errors on ductility and strength reduction factor. It must be noted here that μ=1 and R=1 indicates the elastic cases.

Considering the error plots as functions of ductility and strength reduction factor (dependency graphs) with respect to 'exact' values in terms of maximum top displacement, as given in Figures 4.13-4.14 and Figures A.7.1-A.7.14, the error ratios generally tended to decrease with increasing degrees of inelasticity for low-rise frames. In contrast, for mid- to high-rise frames, the general trend was to increase with increasing levels of ductility. The strength reduction factor dependency was similar to the ductility dependency in most of the cases. This shows that the accuracy of predictions depend on the degree of inelasticity in all cases such that the degree of under-estimation increases for low-rise frames whereas the opposite trend is observed for mid- to high-rise frames.

Figures 4.15-4.16 and Figures A.7.15-A.7.28 showed that in maximum inter-story drift ratio predictions, the ratios tended to decrease for low-rise frames as the inelasticity degree increased. In mid- to high- rise frames, the general tendency was an increase in the amount of under-estimation with increasing ductility level, leading to over-estimations at large ductility values. Moreover, the dependencies on strength reduction factor again generally complied with the ductility dependencies except that in a few cases FEMA and 75%V_y showed insignificant opposite trends between μ and R.

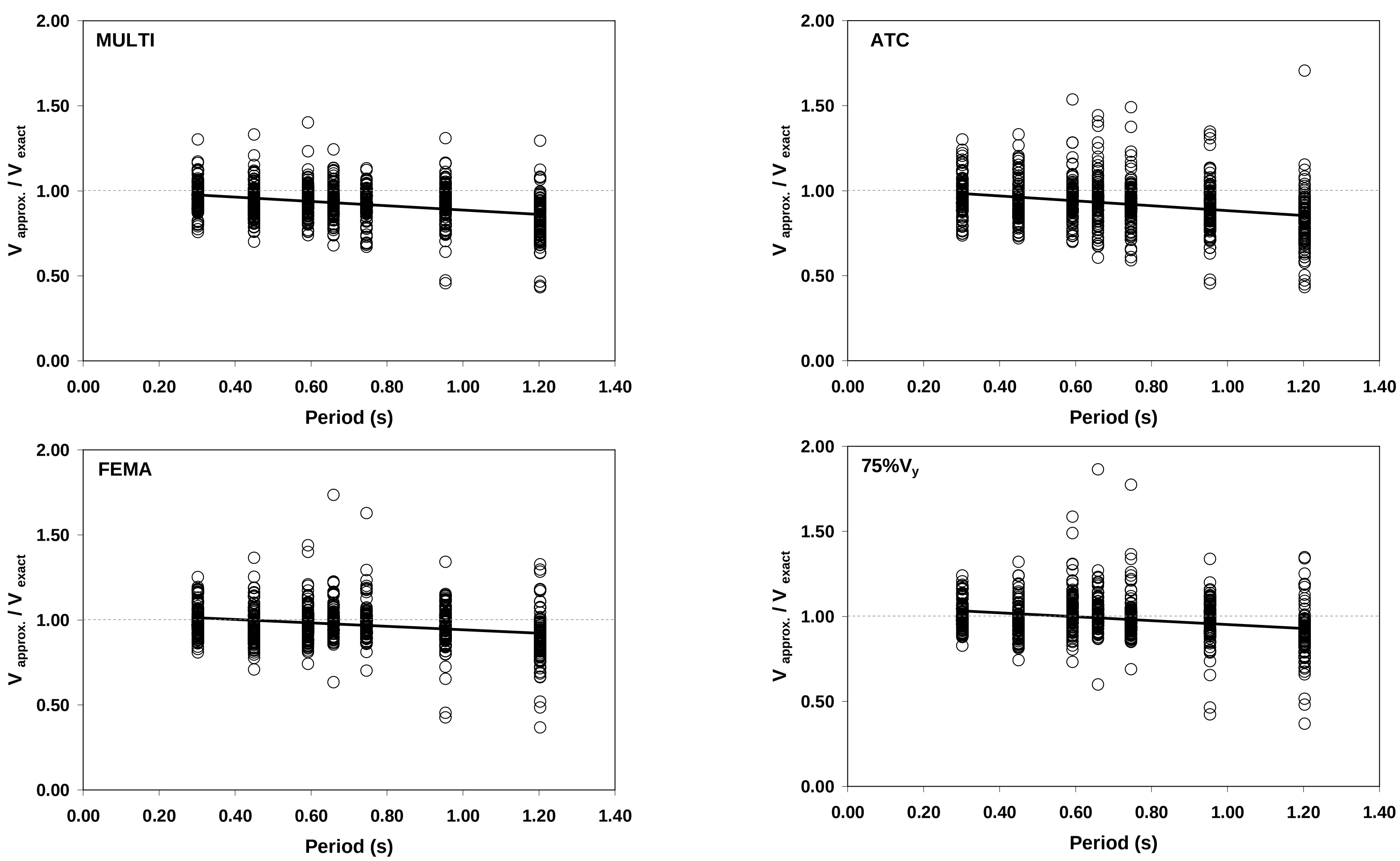

Figure 4.12 Dependency on Period (Maximum Base Shear)

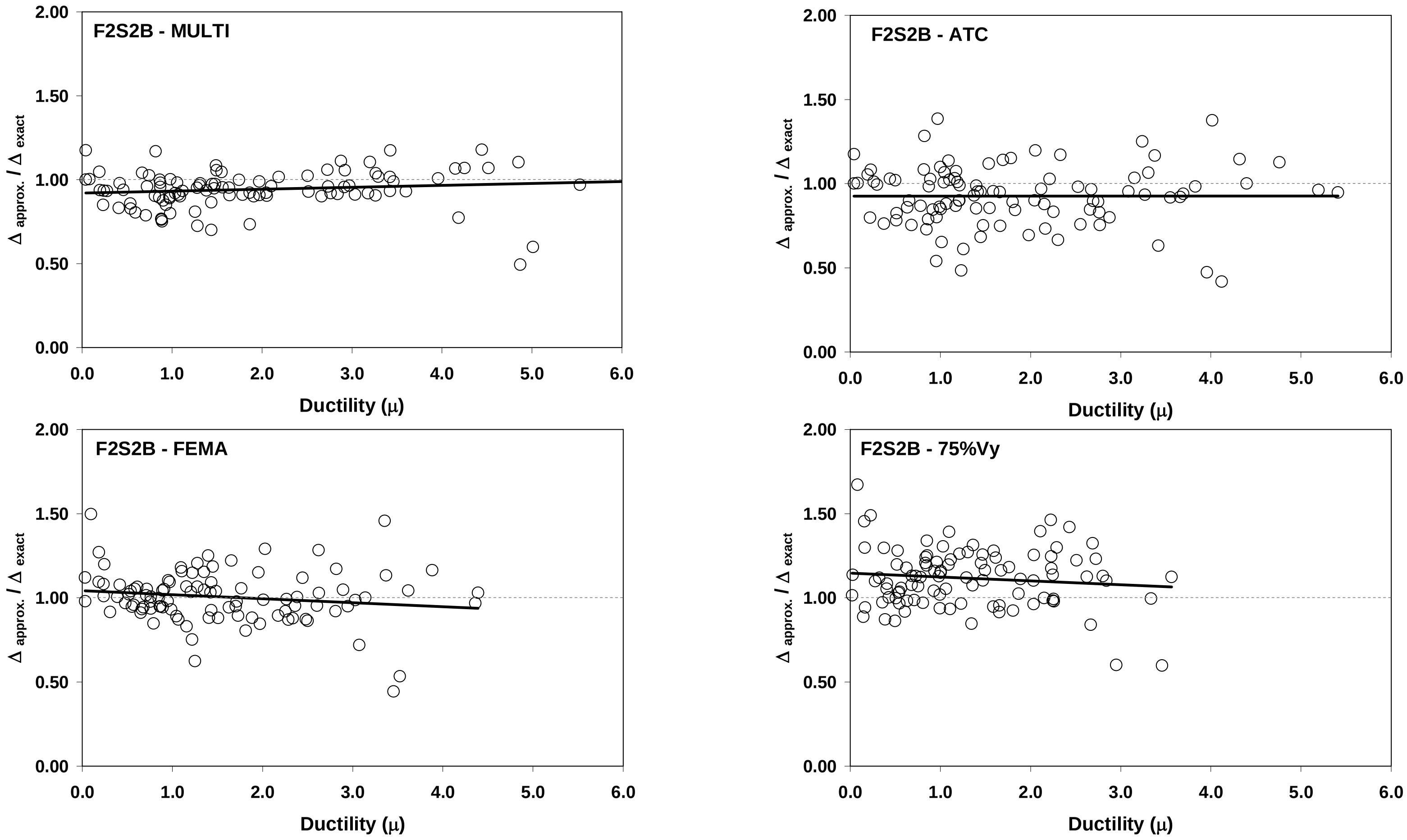

Figure 4.13 Dependency on Ductility (Frame ‘F2S2B’ – Maximum Top Displacement)

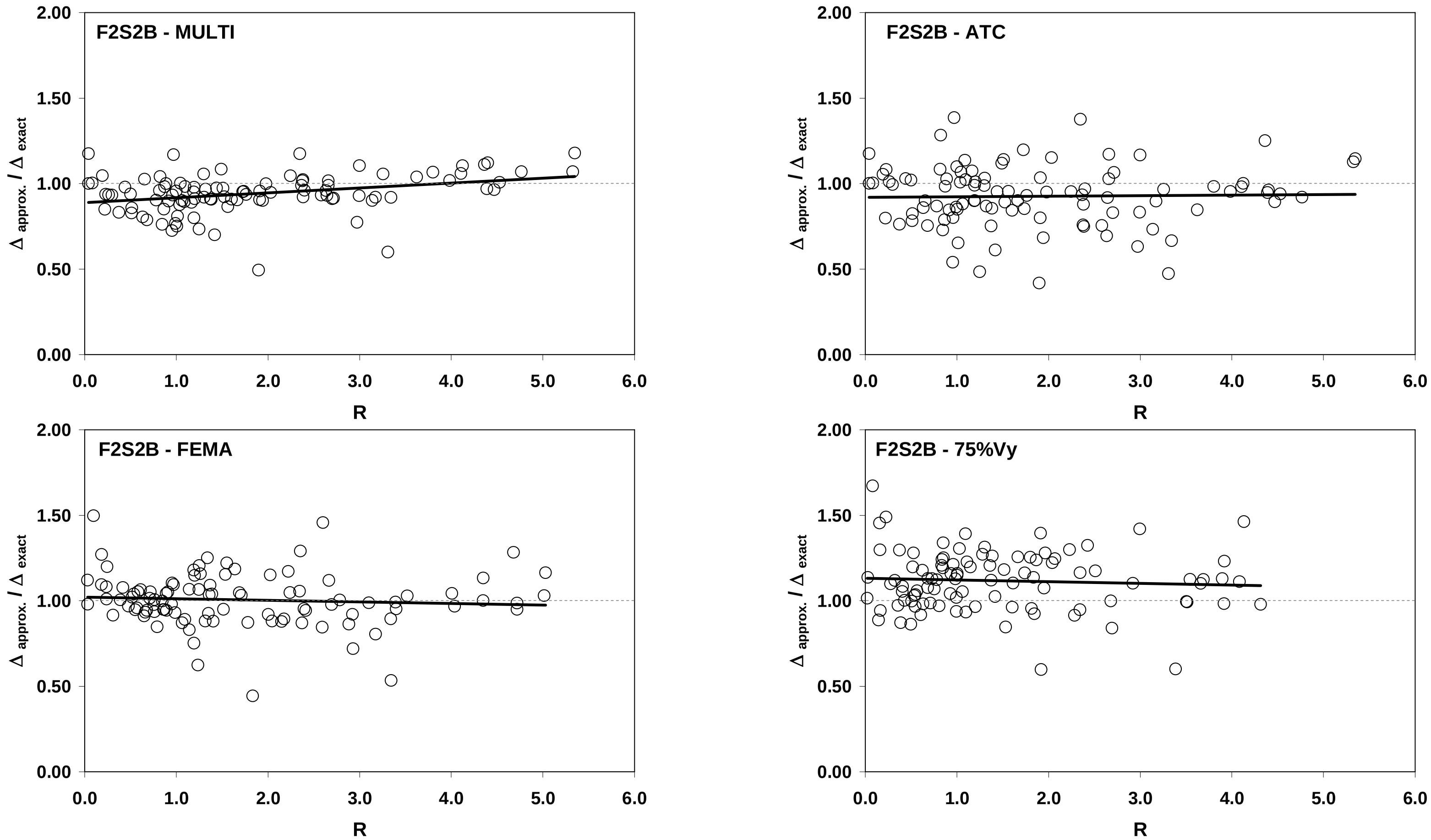

Figure 4.14 Dependency on Strength Reduction Factor (Frame ‘F2S2B’ – Maximum Top Displacement)

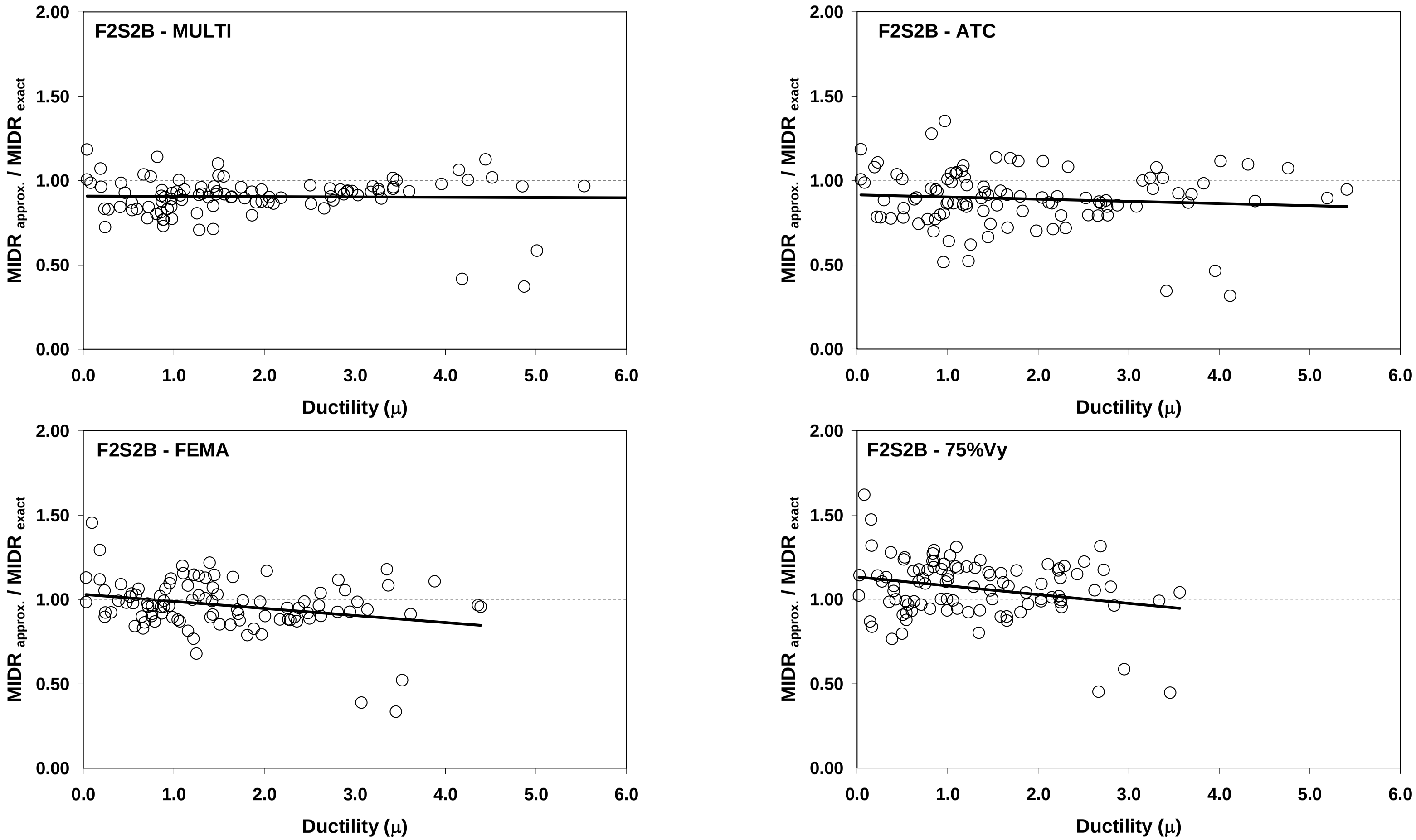

Figure 4.15 Dependency on Ductility (Frame ‘F2S2B’ – Maximum Inter-Story Drift Ratio)

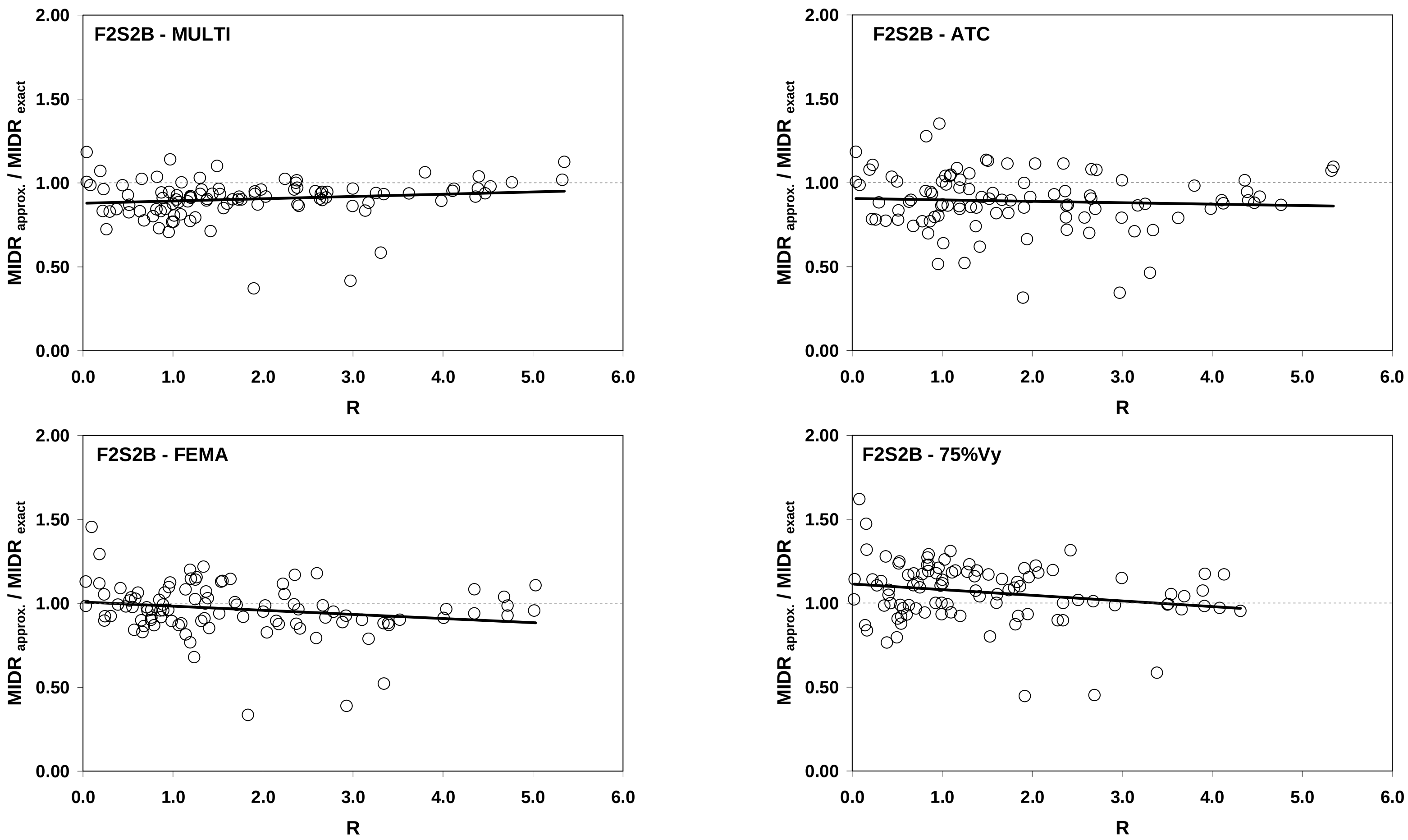

Figure 4.16 Dependency on Strength Reduction Factor (Frame ‘F2S2B’ – Maximum Inter-Story Drift Ratio)

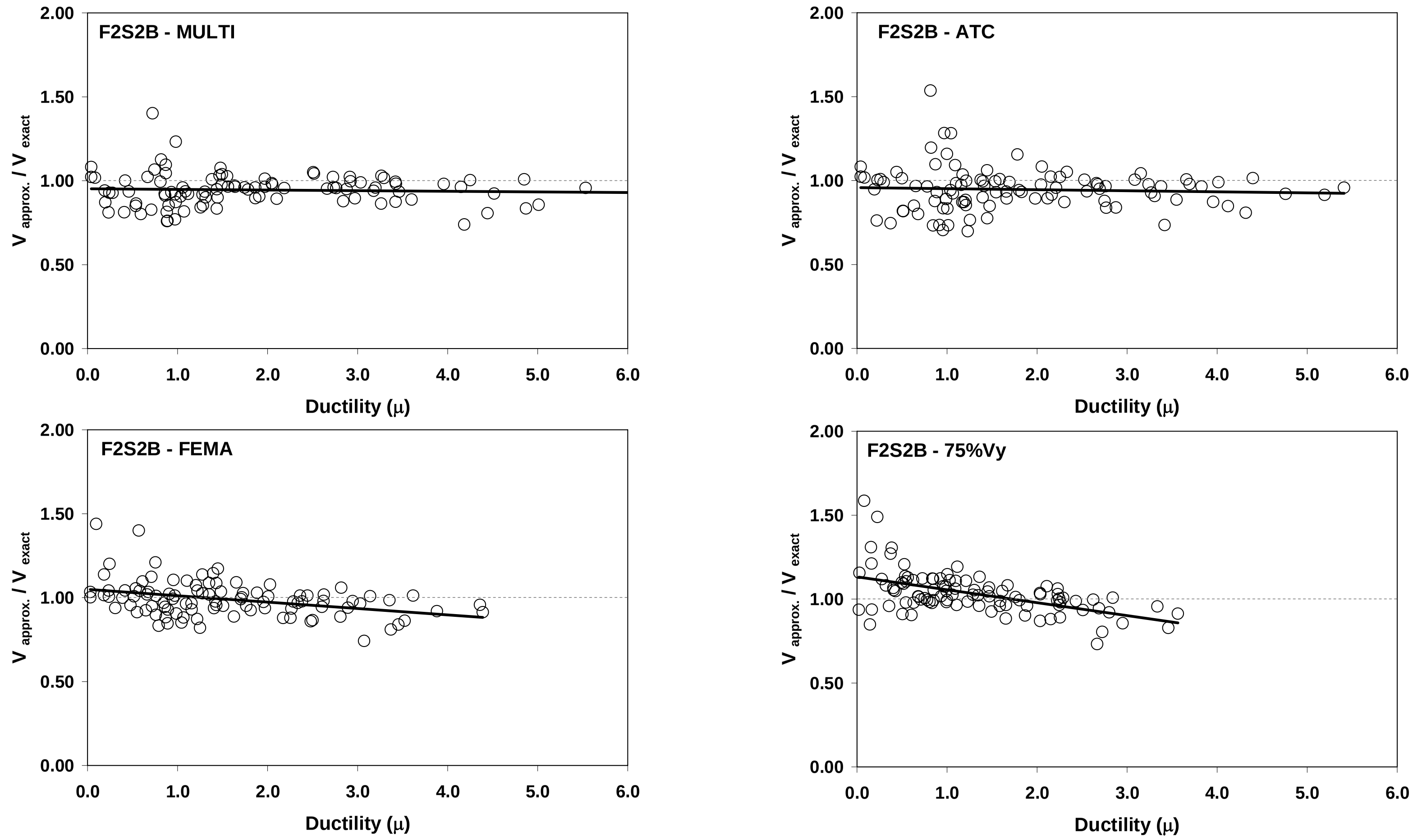

Figure 4.17 Dependency on Ductility (Frame 'F2S2B' – Maximum Base Shear)

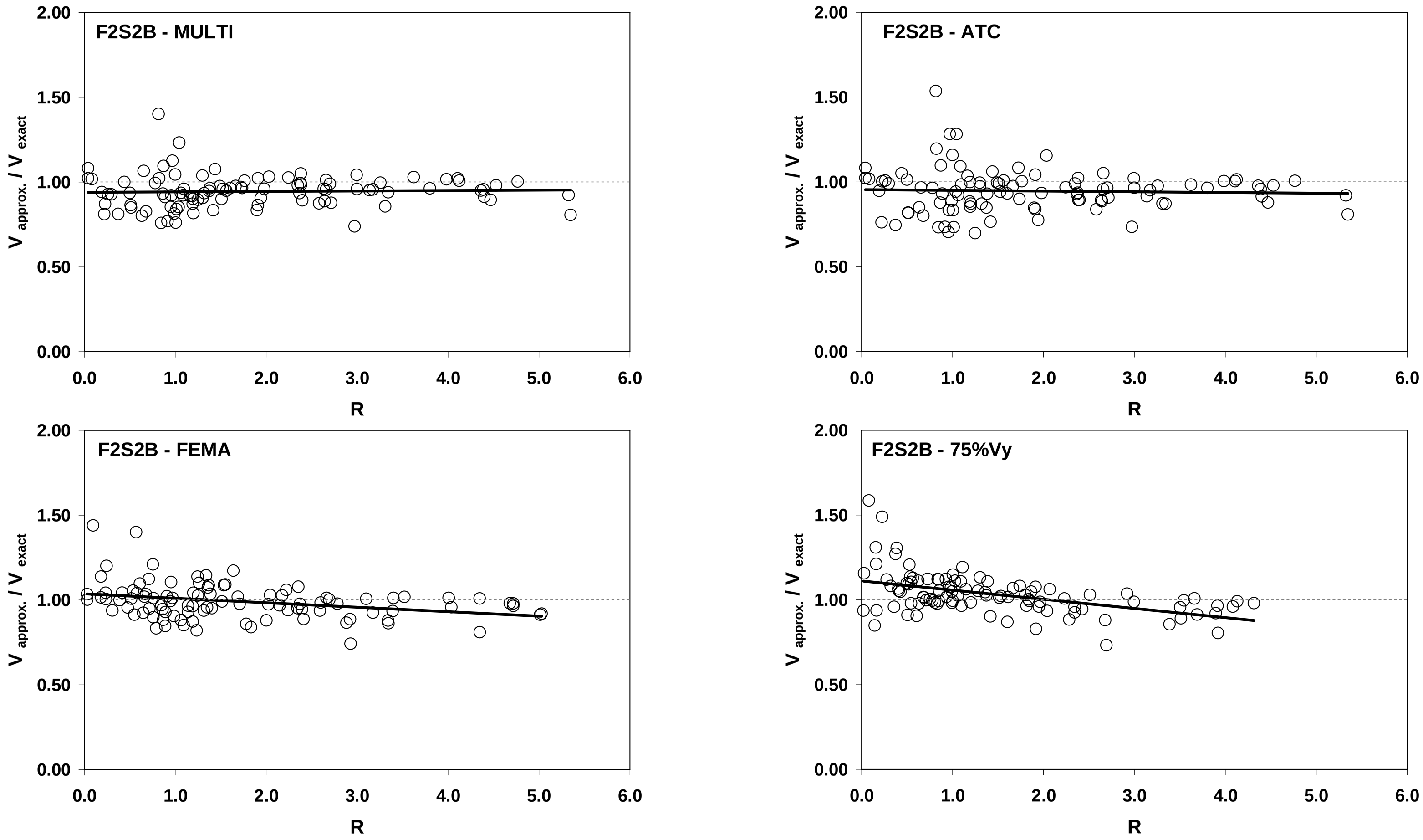

Figure 4.18 Dependency on Strength Reduction Factor (Frame ‘F2S2B’ – Maximum Base Shear)

It was observed in the trend graphs of maximum base shear force demand predictions, as depicted in Figures 4.17-4.18 and Figures A.7.29-A.7.42, that no systematic trend was present all over the cases. However, it could be said that for FEMA and 75%V_y methods the ratios showed a general tendency to decrease with increasing ductility and strength reduction factor levels.

4.3 SUMMARY OF COMPARISONS

The comparison of most widely employed demand parameters computed from approximations employed with the exact results were presented in the previous sections. These comparisons were made at different drift, ductility and strength reduction values to investigate the accuracy of the approximations in the elastic as well as inelastic response regions. The overall evaluations, as summarized in Tables 4.4-4.6, suggest no superiority of one approach over the others. The behavior, in general, seemed to have a mild dependency on the level of inelastic response.

Table 4.4 Error Statistics for Maximum Top Displacement Estimations

FRAME	MULTI		ATC		FEMA		75%V_y	
	Mean	**σ**	**Mean**	**σ**	**Mean**	**σ**	**Mean**	**σ**
F2S2B	0.942	0.115	0.926	0.179	1.005	0.157	1.117	0.173
F2S2B2	0.930	0.114	0.930	0.150	0.971	0.122	0.984	0.111
F3S2B	0.939	0.125	0.946	0.169	0.982	0.154	1.005	0.138
F5S2B	0.940	0.134	0.947	0.221	1.064	0.201	1.078	0.210
F5S4B	0.928	0.096	0.907	0.161	1.005	0.112	1.014	0.110
F5S7B	0.925	0.086	0.937	0.216	1.055	0.146	1.088	0.152
F8S3B	0.922	0.102	0.897	0.155	1.021	0.139	1.029	0.135

Table 4.5 Error Statistics for Maximum Inter-Story Drift Ratio Estimations

FRAME	MULTI		ATC		FEMA		75%V_y	
	Mean	**σ**	**Mean**	**σ**	**Mean**	**σ**	**Mean**	**σ**
F2S2B	0.904	0.121	0.891	0.172	0.965	0.155	1.065	0.176
F2S2B2	0.941	0.110	0.941	0.142	0.981	0.115	0.994	0.104
F3S2B	0.944	0.120	0.951	0.160	0.985	0.144	1.007	0.128
F5S2B	0.903	0.151	0.913	0.246	1.033	0.223	1.049	0.232
F5S4B	0.917	0.116	0.895	0.178	0.997	0.137	1.007	0.135
F5S7B	0.901	0.117	0.922	0.258	1.037	0.185	1.071	0.181
F8S3B	0.812	0.156	0.785	0.171	0.905	0.188	0.913	0.189

Table 4.6 Error Statistics for Maximum Base Shear Estimations

FRAME	**MULTI**		**ATC**		**FEMA**		**75%V_y**	
	Mean	**σ**	**Mean**	**σ**	**Mean**	**σ**	**Mean**	**σ**
F2S2B	0.945	0.097	0.947	0.127	0.990	0.107	1.032	0.124
F2S2B2	0.967	0.092	0.971	0.115	1.001	0.090	1.010	0.081
F3S2B	0.939	0.100	0.948	0.120	0.965	0.108	0.976	0.100
F5S2B	0.924	0.089	0.929	0.139	0.985	0.111	0.994	0.129
F5S4B	0.921	0.125	0.908	0.150	0.968	0.128	0.973	0.128
F5S7B	0.943	0.100	0.952	0.156	1.013	0.119	1.030	0.132
F8S3B	0.833	0.132	0.828	0.165	0.886	0.152	0.890	0.153

FEMA approach provides better predictions for the mean seismic demand parameters due to smaller initial stiffness which appears to have more influence than the yield strength. ATC-40 and MULTI linear approximations produce similar results and generally underestimate the mean response.

In general, the exact representation of the pushover curve called as MULTI under-estimated the ‘exact’ results with the mean error remaining within 20%. Although, the dispersion in the results was found to be the smallest compared to other alternatives, unlike the expectations the predictions were not the most accurate ones. This finding calls for more in-dept and elaborate examination of the results. Possible legitimate explanation appears to be the lack of representing the actual behavior only through the pushover curve. Recalling generally stated reasons for inaccurate results obtained from approximate procedures such as inability to reflect higher mode effects, inadequate representation of hysteretic behavior and the lack of including redistribution leading to inaccurate hinge distributions, the set of ground motion records included might also have played an important role.

In certain cases, the effect of the ground motion on the results that show large variation between the exact and the approximate ones could partly be explained by investigating the response spectra of the specific records. The three data points displayed in Figures 4.1 and 4.2 indicate that the exact time history analysis results corresponding to three ground-motion records are underestimated by a large margin. Similar observation was also made for frames F5S2B and F5S7B. As in the case illustrated in Figure 4.19, for frames F2S2B (T_1=0.59 s), F5S2B (T_1=0.75 s) and F5S7B (T_1=0.66 s), the records 77, 81 and 93 had more destructive effect than the ground motion 92 by causing higher seismic demands although record 92 has larger spectral acceleration at the fundamental period in certain cases. This situation was believed to be related to the shape and area under the response spectra. As the seismic excitation pushes the structure into the inelastic range, the increase in the spectral ordinates corresponding to the elongated period of the structure imposes large demands. According to Figure 4.19, as the period increases, the pseudo-acceleration that this deformed system will be exposed also increases under the ground motions 77, 81 and 93, which is not the case for record 92. This large demand can be captured by the nonlinear time history analyses of the MDOF system. Equivalent SDOF systems seem to be unable to reflect this. Consequently, higher seismic demands in terms of roof displacement and critical inter-story drift ratio are attained by MDOF systems.

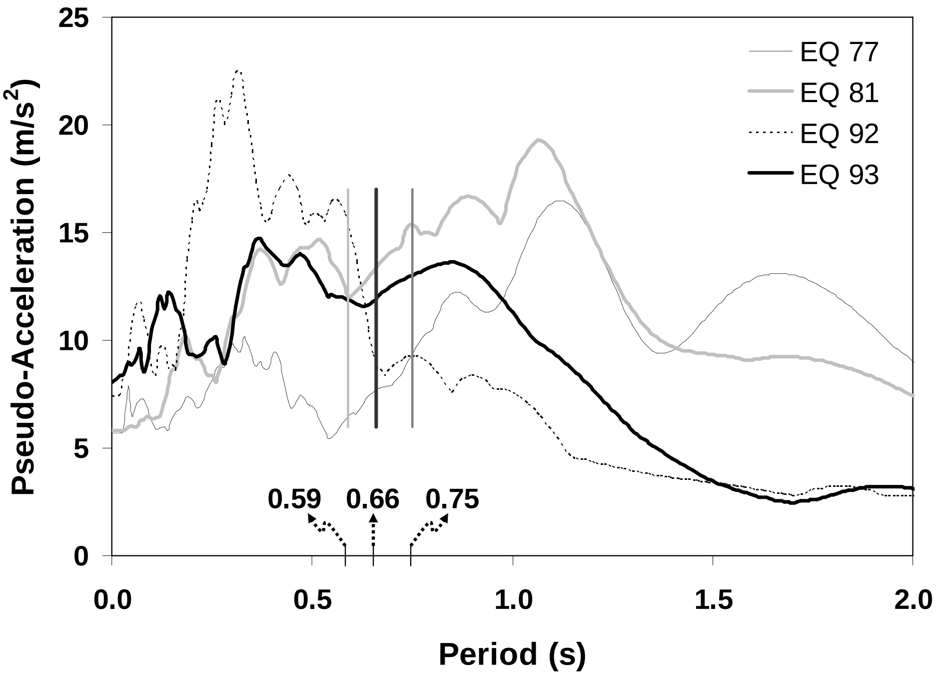

Figure 4.19 Response Spectra for Ground Motions 77, 81, 92 and 93

Ignoring all these factors which are common to all methods of approximations employed in this study, it is expected to obtain the most accurate results from MULTI that describes the pushover curve the best. It appears that the idealization of the pushover curve using MULTI reduces the dispersion significantly but does not improve prediction of the mean demand values. So, bi-linearizing the capacity curve using a reasonable approach such as FEMA would yield relatively good results. FEMA approach appears to be a conservative approach with smaller dispersion than ATC method.

As it was expressed previously, the bi-linear approximation methods were also compared with the results of MULTI method in order to evaluate the performance of the methods at capturing the global behavior. The interpretations made over these comparisons can be found in Appendix B. It has been observed that correlation between the MULTI method and other procedures is quite high for all response parameters investigated here. ATC method generally provides similar results with the MULTI approach especially in the elastic range since both procedures use the same initial stiffness. Although, errors with respect to MULTI method were in certain cases over 50%, the predictions in the mean parameters were generally within 20 percent. These comparisons verify that the simplified approaches employed provide reasonable results as compared to the MULTI method which provides the most accurate representation of the actual capacity curve.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

A comprehensive research has been undertaken to evaluate the influence of several existing alternatives used for approximating capacity curves on seismic demands. In order to achieve this goal, seven reinforced concrete frames were analyzed under nearly 100 ground motions utilizing OpenSees. Firstly, nonlinear time history analyses were conducted to compute the ‘exact’ seismic demands in terms of maximum top displacement, maximum inter-story drift ratio and maximum base shear under given ground motions. After obtaining the seismic responses, nonlinear static analyses namely pushover analyses were conducted to obtain the global behavior of each frame based on ‘elastic first mode’ lateral load pattern. The capacity curve of each frame was later approximated using four alternative methods:

- In MULTI method, the capacity curve was approximated using many linear segments to fully describe the curve.
- In ATC method, the curve was approximated using the initial stiffness approach as ATC-40 recommends.
- In FEMA method, the pushover curve was idealized using the effective secant stiffness approach by applying FEMA-356 propositions.
- In modified FEMA method (75%V_y), the capacity curves was idealized again using an effective secant stiffness approach but this time the recommendations of Paulay and Priestley [17] were followed in conjunction with equal energy rule.

Based on the idealized capacity curves, equivalent SDOF models of MDOF systems were formed and analyzed under the same ground motion set. From these simplified nonlinear dynamic analyses, approximate top displacement demands were found and at these target displacements, drift and force demands were computed in conjunction with the results of pushover analyses.

The approximate seismic demands were then compared with the ‘exact’ results of nonlinear time history analyses and the performance of each idealization alternative at predicting exact responses were evaluated at various levels of inelasticity. Additionally, the dependency of prediction errors on ductility, strength reduction factor and period was also investigated. Apart from the comparisons with respect to ‘exact’ results, the predictions of bi-linearization methods were also compared with the results of MULTI method. This comparison was made in order to evaluate the common methods at predicting the global behavior that was thought to be better presented by fully described capacity curve rather than predicting individual nonlinear time history analysis results.

5.2 CONCLUSIONS

Based on the interpretations made over the comparisons of simplified analysis results with ‘exact’ results, following conclusions were drawn:

- No method seems to be clearly superior in all cases at predicting the exact seismic response parameters in terms of roof displacement, maximum inter-story drift and base shear force.
- All methods generally estimate the seismic demand parameters with 20 percent mean error. Although the order of mean errors of the approximations is very similar, ATC method shows a great variation in the results and generally yields underestimation of seismic response parameters. Similar to ATC method, MULTI method under-estimates the demands, but the dispersion in MULTI method’s results is the smallest among the approximation alternatives employed. FEMA and 75%V_y methods, however, generally over-estimate the response parameters with slightly larger scatter.
- It appears that accurate representation of the pushover curve does not improve mean results significantly. However, it reduces the uncertainty in the predictions.

- It seems that other factors such as hysteretic behavior (loading-unloading model), ground motion characteristics and frame properties play more important role than the accurate representation of the capacity curve.
- The maximum top displacement prediction performance of approximation alternatives does not seem to depend on period. In contrast, for the global force demand predictions, all methods tend to under-estimate the exact demand with increasing period. Moreover, MULTI and ATC methods' under-estimation of maximum inter-story drift demands also decrease with increasing period.
- The behavior, in general, seems to be not significantly depending on the degree of inelastic response. That is, no general trend in the prediction errors is observed with an increase in both ductility level and strength reduction factor.
- For frames whose idealized capacity curves do not differ very much from each other, the yield definitions for displacement and strength would also not be so different from each other. However, for frames that do have parabolic capacity curves with unclear yield point, the approximations would yield very contrasting yield definitions.
- Although MULTI seems to provide relatively better results, due to difficulty of its representation simpler models such as FEMA and ATC are recommended.
- Among the simpler idealization methods, FEMA approach appears to be a conservative approach with smaller dispersion than ATC method, thus it would be better to use FEMA method in order to estimate the seismic demand parameters in terms of top displacement, maximum inter-story drift and base shear force.

In addition to the evaluation of the approximation alternatives at predicting the exact results, ATC, FEMA and 75%V_y methods were also evaluated at estimating the response parameters with respect to global behavior that was represented by MULTI method. ATC method seems to be definitely exceptional in all cases by correlating very well with MULTI method results. FEMA and 75%V_y methods generally over-estimate the displacement and drift demands and the degree of over-estimation seems to decrease with increasing period, ductility and strength reduction factor. However, the mean errors remain in reasonable limits supporting the idea that bi-linear models can be used in simplified analyses instead of the complex model formed by multi-linear segments.

5.3 FUTURE STUDY RECOMMENDATIONS

Seven reinforced concrete frames, which do not have strength degradation in their nonlinear static response, were analyzed in this study. Although the fundamental period of vibration distribution was almost uniform, the study should be broadened with a larger frame database of having various fundamental periods and global behavior characteristics. Degrading models might also be included in an extended study to evaluate the effects of idealized pushover curves on these building types.

Although 100 ground motions were employed in this study to push the structures into various degrees of inelasticity, the equality of number of results at each ductility level could not have been satisfied, i.e. the inelasticity was not evenly distributed under given ground motion set. Thus, in order to have a better statistical distribution, larger ground motion database may be utilized or present earthquakes may be scaled to generate new ones.

An assumption was made when idealizing the capacity curves that the maximum displacement was always assumed to be at 2.5% global drift of the building and the last point of the idealized curve was defined accordingly. In the future studies, either the effect of this assumption should be identified or this assumption might be disregarded by updating the trial performance point at each step which would increase computational steps.

In the nonlinear dynamic analyses of equivalent SDOF systems, non-degrading SDOF systems with kinematic hardening type were used. The studies should be extended to include also the degrading models.

Apart from equivalent SDOF analyses on the approximated capacity models, seismic response calculations using Capacity Spectrum Method and Displacement Coefficient Method might be also studied in order to investigate and include the effects of further approximations that are present in approximate procedures.

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APPENDIX A

FRAME DATA, RESULTS AND COMPARISON OF ANALYSES

A.1 DESCRIPTION OF SELECTED FRAMES

A.1.1 F2S2B

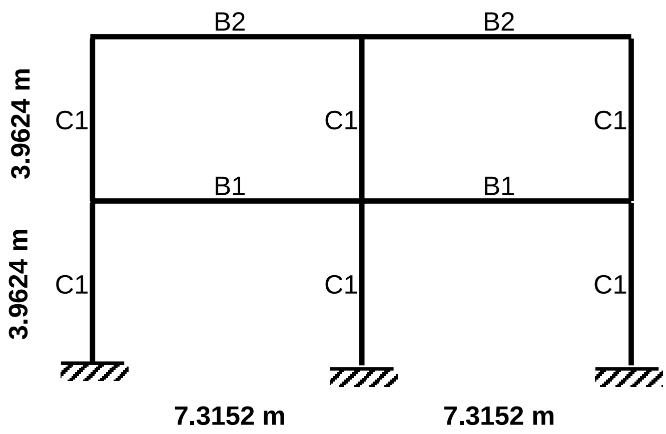
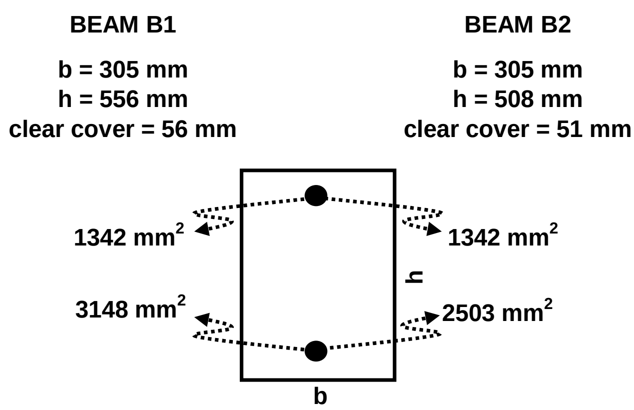
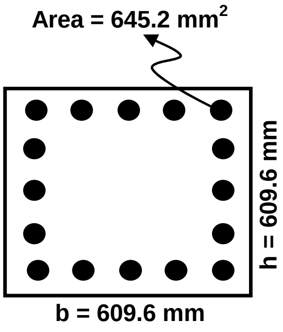


Figure A.1.1 Frame F2S2B



COLUMN C1



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Material Properties				
Unconfined Concrete Properties				
Section	**f_c (MPa)**	**ε_{c0}**	**f_{cu} (MPa)**	**ε_{cu}**
All	26.000	0.002	0.001	0.0057
Confined Concrete Properties				
Section	**f_{cc} (MPa)**	**ε_{c0c}**	**f_{cuc} (MPa)**	**ε_{cuc}**
C1	34.153	0.0026	6.831	0.048
B1	29.692	0.0023	5.938	0.017
B2	29.670	0.0023	5.934	0.018
Reinforcing Steel Properties				
Section	**f_y (MPa)**	**f_{yw} (MPa)**	**Hardening Ratio**	**E (MPa)**
All	494.000	494.000	0.005	200000

Modal Properties	
T_1 (s)	0.592
T_2 (s)	0.174

Story Masses	
Story	**Mass (ton)**
1	177.7014
2	97.5535

Beam Loading (kN/m)		
Beam	**DL**	**LL**
B1	24.71	1.95
B2	19.23	0.98

A.1.2 F2S2B2

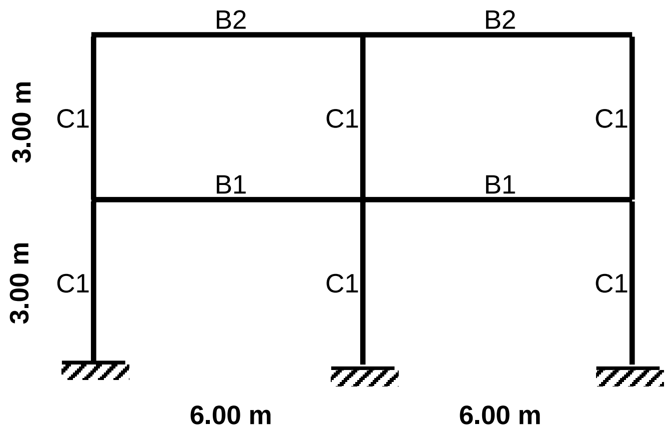
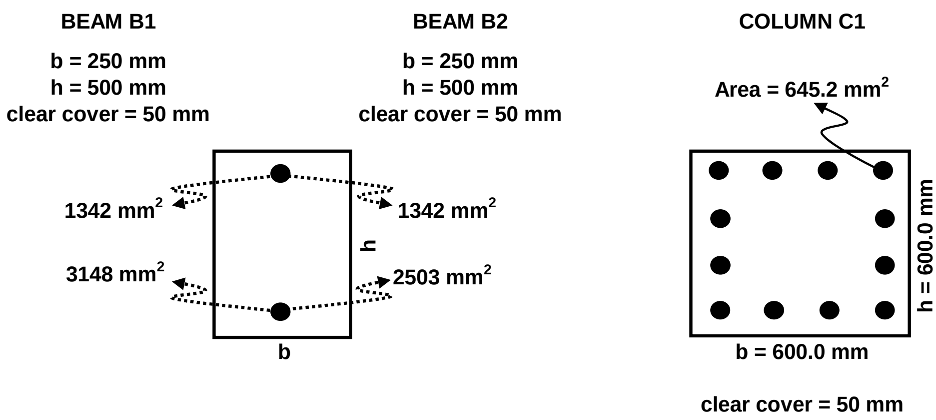


Figure A.1.2 Frame F2S2B2



Material Properties				
Unconfined Concrete Properties				
Section	f_c (MPa)	ε_{c0}	f_{cu} (MPa)	ε_{cu}
All	26.000	0.002	0.001	0.0057
Confined Concrete Properties				
Section	f_{cc} (MPa)	ε_{c0c}	f_{cuc} (MPa)	ε_{cuc}
C1	33.422	0.0026	6.684	0.045
B1	30.552	0.0024	6.110	0.018
B2	30.552	0.0024	6.110	0.018
Reinforcing Steel Properties				
Section	f_y (MPa)	f_{yw} (MPa)	Hardening Ratio	E (MPa)
All	494.000	494.000	0.005	200000

Modal Properties	
T_1 (s)	0.302
T_2 (s)	0.089

Story Masses	
Story	Mass (ton)
1	88.851
2	48.777

Beam Loading (kN/m)		
Beam	DL	LL
B1	12.36	0.98
B2	9.62	0.49

A.1.3 F3S2B

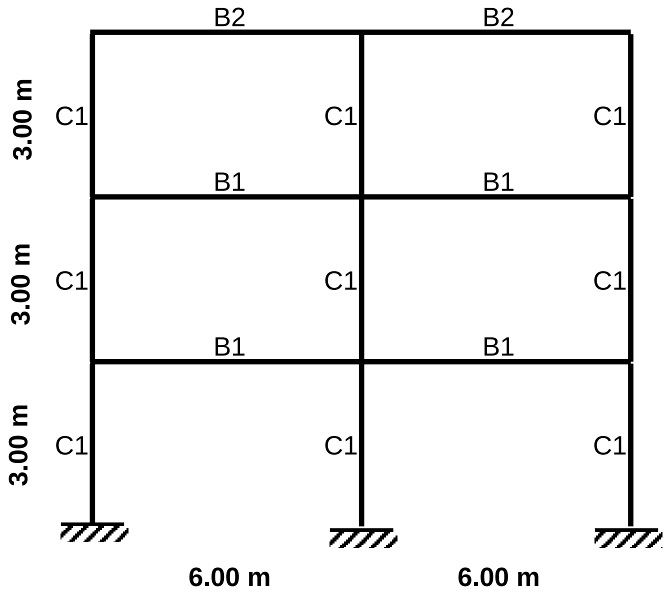
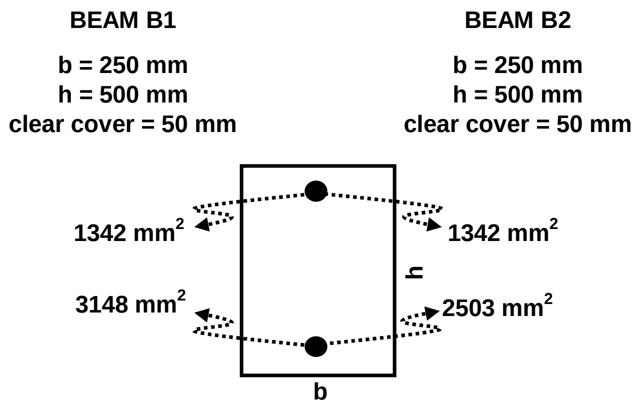
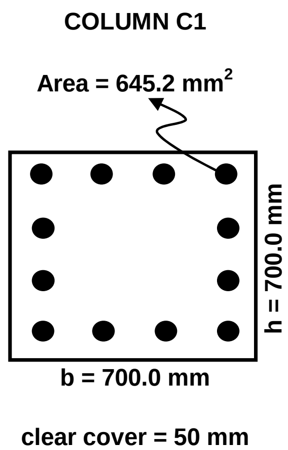


Figure A.1.3 Frame F3S2B





Material Properties				
Unconfined Concrete Properties				
Section	**f_c (MPa)**	**ε_{c0}**	**f_{cu} (MPa)**	**ε_{cu}**
All	26.000	0.002	0.001	0.0057
Confined Concrete Properties				
Section	**f_{cc} (MPa)**	**ε_{c0c}**	**f_{cuc} (MPa)**	**ε_{cuc}**
C1	33.422	0.0026	6.684	0.045
B1	30.552	0.0024	6.110	0.018
B2	30.552	0.0024	6.110	0.018
Reinforcing Steel Properties				
Section	**f_y (MPa)**	**f_{yw} (MPa)**	**Hardening Ratio**	**E (MPa)**
All	494.000	494.000	0.005	200000

Modal Properties	
T_1 (s)	0.450
T_2 (s)	0.118
T_3 (s)	0.058

Story Masses	
Story	**Mass (ton)**
1	88.851
2	88.851
3	48.777

Beam Loading (kN/m)		
Beam	**DL**	**LL**
B1	12.36	0.98
B2	9.62	0.49

A.1.4 F5S2B

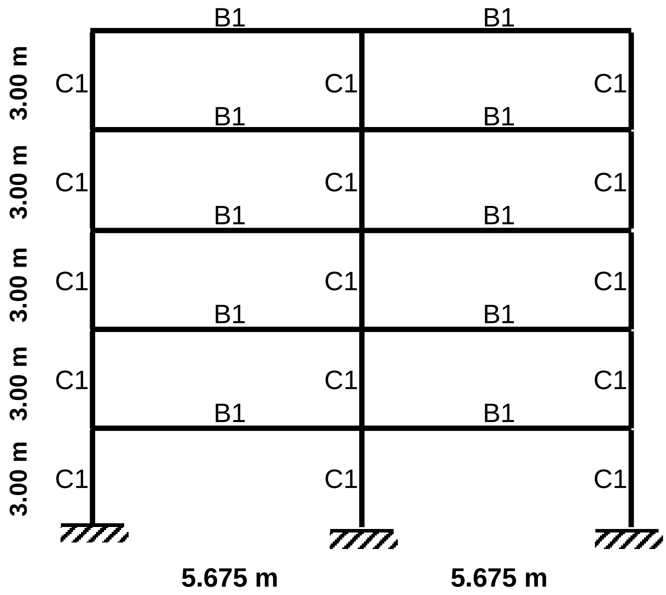
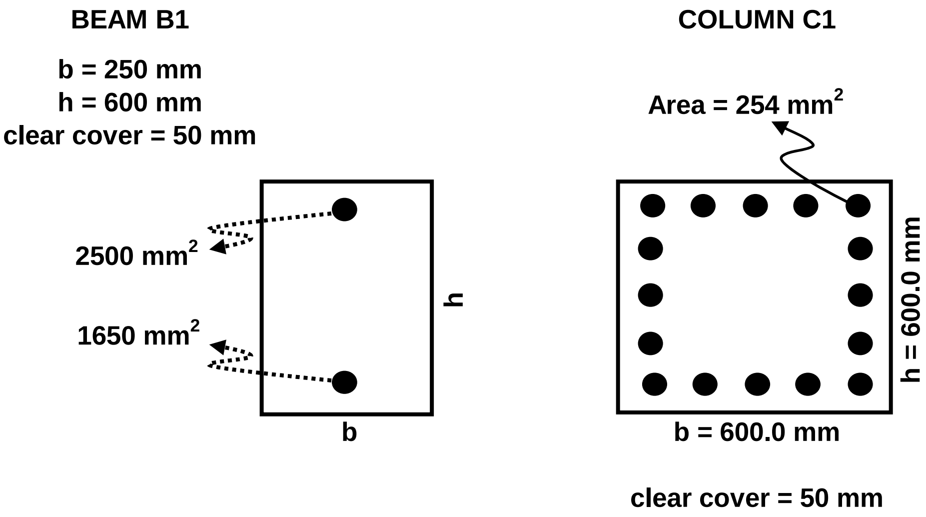


Figure A.1.4 Frame F5S2B



Material Properties				
Unconfined Concrete Properties				
Section	**f_c (MPa)**	**ε_{c0}**	**f_{cu} (MPa)**	**ε_{cu}**
All	20.000	0.002	0.001	0.0075
Confined Concrete Properties				
Section	**f_{cc} (MPa)**	**ε_{c0c}**	**f_{cuc} (MPa)**	**ε_{cuc}**
C1	26.692	0.0027	5.338	0.049
B1	23.659	0.0024	4.732	0.019
Reinforcing Steel Properties				
Section	**f_y (MPa)**	**f_{yw} (MPa)**	**Hardening Ratio**	**E (MPa)**
All	420.000	420.000	0.005	200000

Modal Properties			
T_1 (s)	0.746	**T_4 (s)**	0.094
T_2 (s)	0.221	**T_5 (s)**	0.072
T_3 (s)	0.113		

Story Masses			
Story	**Mass (ton)**	**Story**	**Mass (ton)**
1	47.505	**4**	52.177
2	52.177	**5**	56.140
3	52.177		

Beam Loading (kN/m)		
Beam	**DL**	**LL**
B1	12.36	0.98
B1 - Top Floor	9.62	0.49

A.1.5 F5S4B

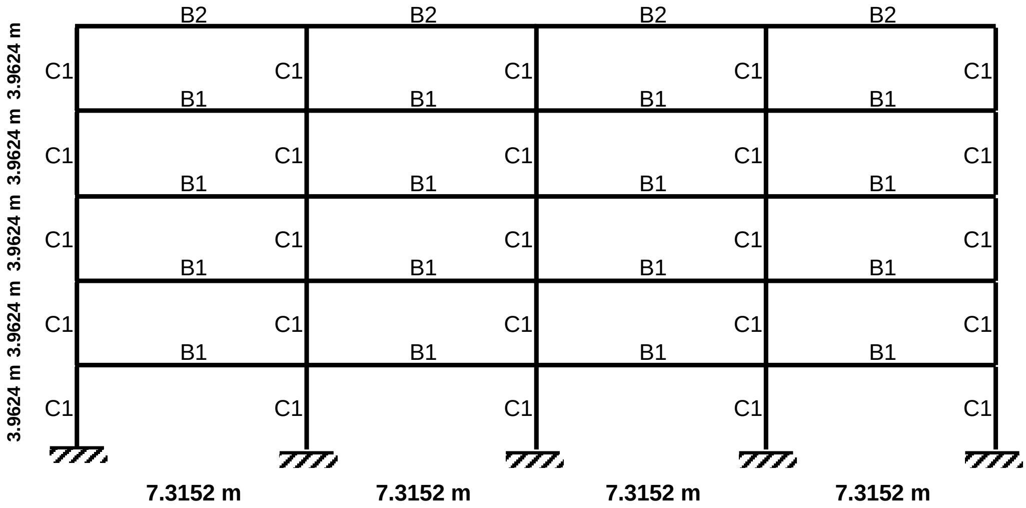
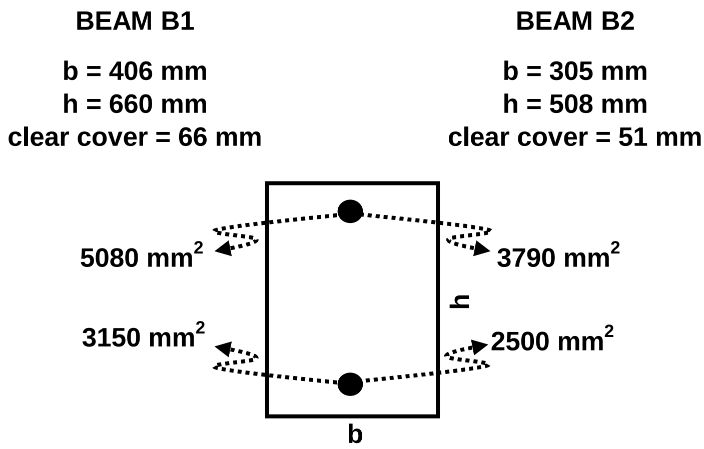
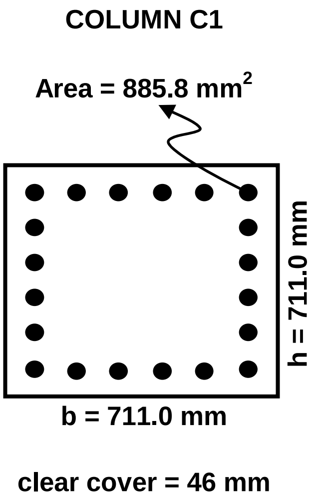


Figure A.1.5 Frame F5S4B





Material Properties				
Unconfined Concrete Properties				
Section	**f_c (MPa)**	**ε_{c0}**	**f_{cu} (MPa)**	**ε_{cu}**
All	28.000	0.002	0.001	0.0054
Confined Concrete Properties				
Section	**f_{cc} (MPa)**	**ε_{c0c}**	**f_{cuc} (MPa)**	**ε_{cuc}**
C1	36.173	0.0026	7.235	0.058
B1	31.997	0.0023	6.399	0.022
B2	33.328	0.0024	6.666	0.024
Reinforcing Steel Properties				
Section	**f_y (MPa)**	**f_{yw} (MPa)**	**Hardening Ratio**	**E (MPa)**
All	459.000	459.000	0.005	200000

Modal Properties			
T_1 (s)	0.954	**T_4 (s)**	0.138
T_2 (s)	0.298	**T_5 (s)**	0.107
T_3 (s)	0.158		

Story Masses			
Story	**Mass (ton)**	**Story**	**Mass (ton)**
1	212.430	**4**	212.430
2	212.430	**5**	157.400
3	212.430		

Beam Loading (kN/m)		
Beam	**DL**	**LL**
B1	20.49	1.31
B2	15.64	0.53

A.1.6 F5S7B

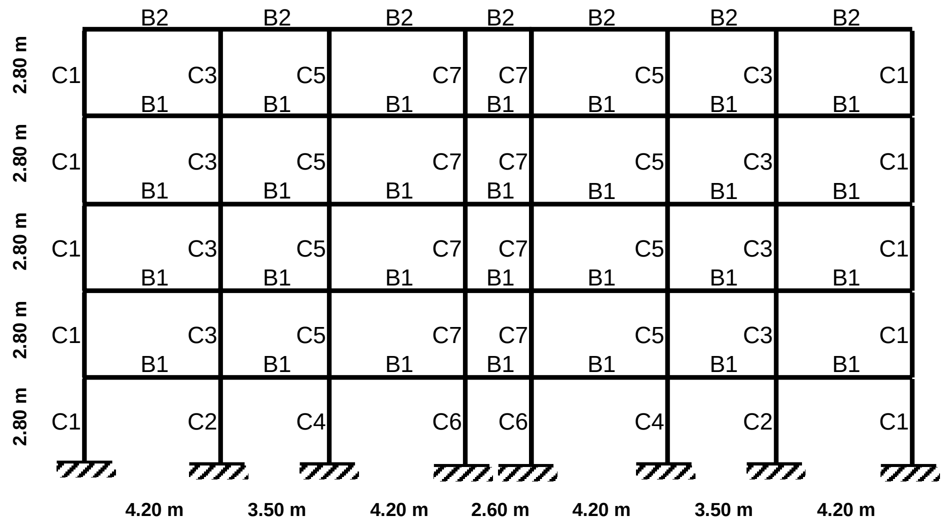
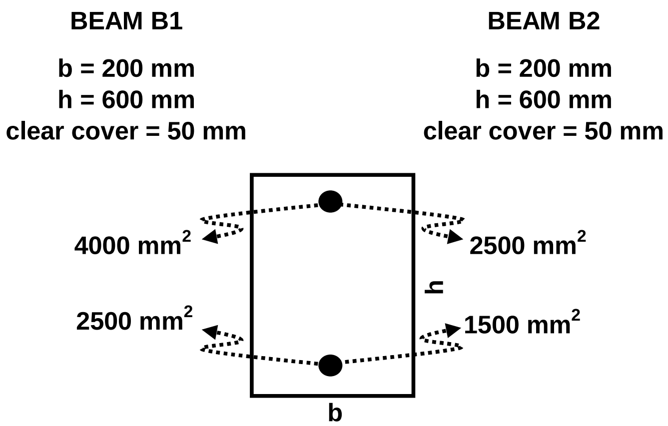
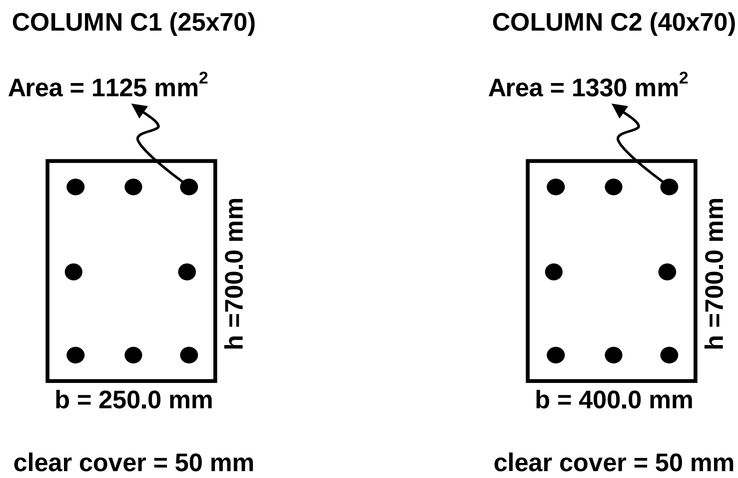
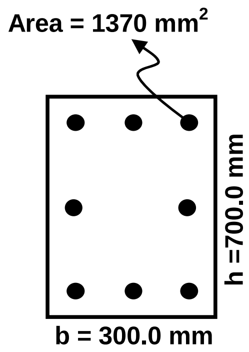


Figure A.1.6 Frame F5S7B





COLUMN C3 (30x70)



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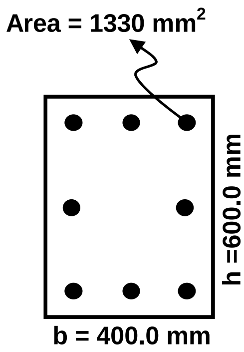
COLUMN C4 (40x60)



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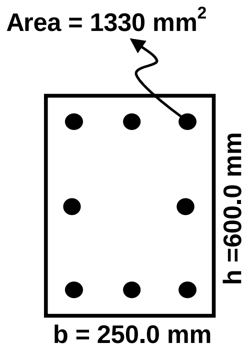
COLUMN C5 (25x70)



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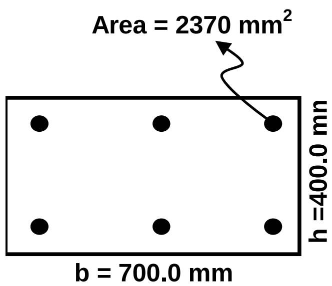
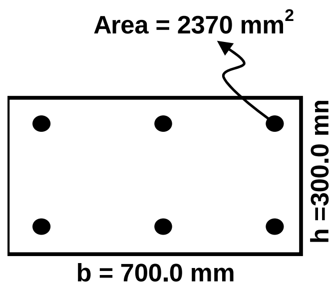
COLUMN C6 (70x40)



clear cover = 50 mm

COLUMN C7 (70x30)



clear cover = 50 mm

Material Properties				
Unconfined Concrete Properties				
Section	**f_c (MPa)**	**ε_{c0}**	**f_{cu} (MPa)**	**ε_{cu}**
All	20.000	0.002	0.001	0.0075
Confined Concrete Properties				
Section	**f_{cc} (MPa)**	**ε_{c0c}**	**f_{cuc} (MPa)**	**ε_{cuc}**
B1	27.917	0.0028	5.583	0.029
B2	27.917	0.0028	5.583	0.029
C1	29.082	0.0029	5.816	0.038
C2	24.224	0.0024	4.845	0.027
C3	25.525	0.0026	5.105	0.028
C4	25.819	0.0026	5.164	0.035
C5	29.659	0.003	5.932	0.040
C6	24.352	0.0024	4.870	0.028
C7	25.704	0.0026	5.141	0.029
Reinforcing Steel Properties				
Section	**f_y (MPa)**	**f_{yw} (MPa)**	**Hardening Ratio**	**E (MPa)**
All	420.000	420.000	0.005	200000

Modal Properties			
T_1 (s)	0.659	**T_4 (s)**	0.127
T_2 (s)	0.219	**T_5 (s)**	0.101
T_3 (s)	0.15		

Story Masses			
Story	**Mass (ton)**	**Story**	**Mass (ton)**
1	150.810	**4**	148.080
2	148.080	**5**	174.070
3	148.080		

Beam Loading (kN/m)		
Beam	**DL**	**LL**
B1 (L=4.20 m)	16.84	4.1
B1 (L=3.50 m)	22.79	4.4
B1 (L=4.20 m)	22.02	5.4
B1 (L=2.60 m)	24.01	6.43
B2 (L=4.20 m)	16.32	3.16
B2 (L=3.50 m)	17.3	3.3
B2 (L=4.20 m)	20.56	4.05
B2 (L=2.60 m)	19.06	3.71

A.1.7 F8S3B

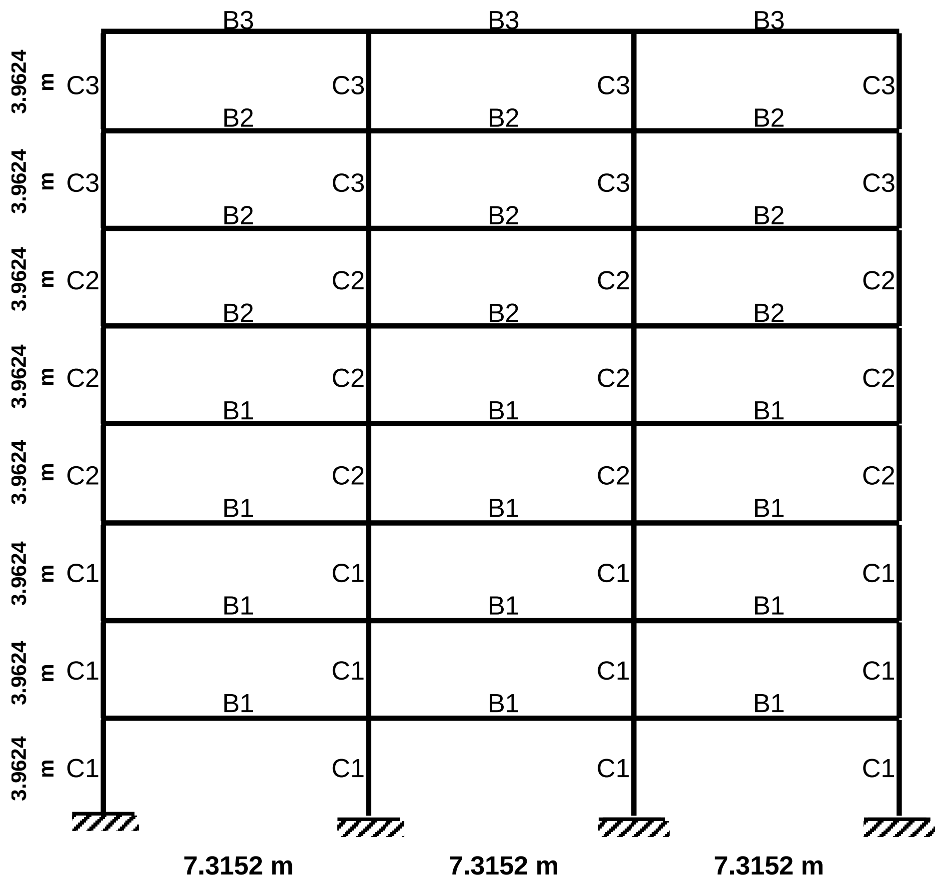
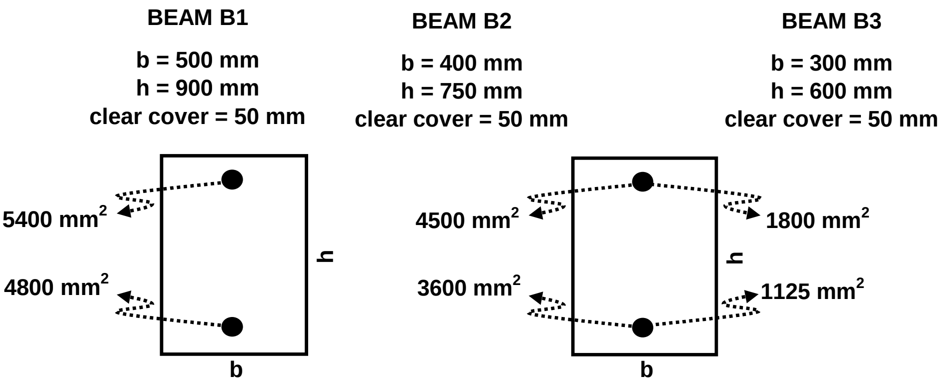
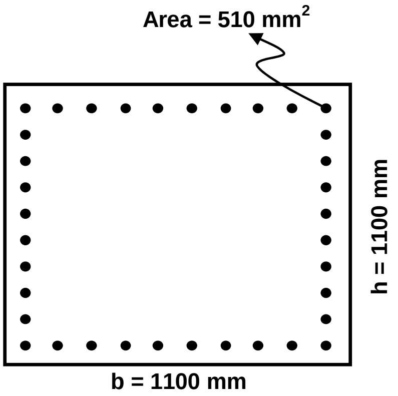


Figure A.1.7 Frame F8S3B

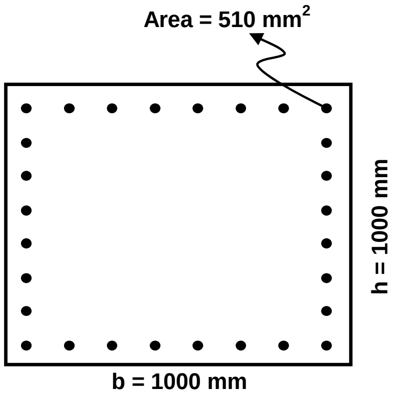


COLUMN C1



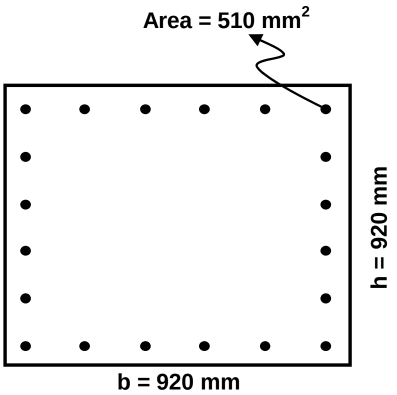
clear cover = 50 mm

COLUMN C2



clear cover = 50 mm

COLUMN C3



clear cover = 50 mm

Material Properties				
Unconfined Concrete Properties				
Section	**f_c (MPa)**	**ε_{c0}**	**f_{cu} (MPa)**	**ε_{cu}**
All	28.000	0.002	0.001	0.0054
Confined Concrete Properties				
Section	**f_{cc} (MPa)**	**ε_{c0c}**	**f_{cuc} (MPa)**	**ε_{cuc}**
B1	30.704	0.0022	6.141	0.019
B2	31.513	0.0023	6.303	0.02
B3	33.047	0.0024	6.609	0.023
C1	33.880	0.0024	6.776	0.053
C2	35.008	0.0025	7.002	0.059
C3	38.367	0.0027	7.673	0.082
Reinforcing Steel Properties				
Section	**f_y (MPa)**	**f_{yw} (MPa)**	**Hardening Ratio**	**E (MPa)**
All	459.000	459.000	0.005	200000

Modal Properties			
T_1 (s)	1.203	**T_5 (s)**	0.262
T_2 (s)	0.481	**T_6 (s)**	0.252
T_3 (s)	0.414	**T_7 (s)**	0.218
T_4 (s)	0.281	**T_8 (s)**	0.2

Story Masses			
Story	**Mass (ton)**	**Story**	**Mass (ton)**
1	230.450	**5**	230.450
2	230.450	**6**	230.450
3	230.450	**7**	230.450
4	230.450	**8**	202.920

Beam Loading (kN/m)		
Beam	**DL**	**LL**
B1	18.64	1.21
B2	18.64	1.21
B3	14.55	0.49

A.2 NONLINEAR TIME HISTORY ANALYSIS RESULTS

Table A.2.1 Nonlinear Time History Results of Frame 'F2S2B'

EQ	V (kN)	Δ (m)	MIDR (%)	EQ	V (kN)	Δ (m)	MIDR (%)
1	36.24	0.002	0.029	51	978.80	0.085	1.272
2	38.45	0.002	0.035	52	1171.65	0.152	2.335
3	183.95	0.012	0.168	53	611.19	0.049	0.810
4	72.30	0.004	0.070	54	1085.10	0.111	1.631
5	165.23	0.010	0.146	55	999.73	0.082	1.230
6	244.50	0.016	0.272	56	1289.05	0.192	2.542
7	398.50	0.027	0.398	57	910.80	0.065	0.949
8	508.84	0.034	0.494	58	1196.33	0.157	2.295
9	801.53	0.066	0.993	59	1385.29	0.198	2.541
10	726.50	0.060	0.898	60	907.69	0.059	0.921
11	408.20	0.027	0.388	61	856.20	0.064	0.970
12	593.89	0.040	0.571	62	1141.75	0.168	2.344
13	768.73	0.059	0.849	63	1162.26	0.140	1.918
14	857.24	0.065	0.927	64	1106.93	0.119	1.828
15	233.46	0.015	0.229	65	614.21	0.050	0.796
16	504.34	0.036	0.526	66	1124.05	0.142	2.178
17	513.72	0.035	0.516	67	1205.27	0.165	2.377
18	663.81	0.049	0.732	68	1053.49	0.109	1.693
19	772.82	0.057	0.802	69	1268.47	0.190	2.528
20	828.67	0.066	0.956	70	1210.67	0.185	2.479
21	795.74	0.063	0.920	71	1098.10	0.122	1.898
22	902.02	0.074	1.110	72	999.66	0.094	1.490
23	534.76	0.040	0.583	73	1376.29	0.202	2.648
24	340.12	0.023	0.341	74	1082.00	0.149	2.255
25	688.27	0.053	0.846	75	1193.00	0.183	2.483
26	978.58	0.090	1.397	76	940.38	0.074	1.166
27	847.79	0.083	1.297	77	1429.80	0.542	9.497
28	802.03	0.062	0.891	78	1320.92	0.171	2.267
29	1009.27	0.099	1.490	79	1162.40	0.173	2.574
30	210.67	0.014	0.271	80	1297.68	0.232	3.219
31	977.42	0.097	1.480	81	1389.88	0.460	6.218
32	880.58	0.085	1.311	82	1258.38	0.214	2.841
33	586.00	0.049	0.739	83	1238.22	0.216	2.943
34	760.67	0.060	0.877	84	1222.69	0.120	1.961
35	543.56	0.038	0.575	85	1310.65	0.169	2.372
36	944.56	0.091	1.388	86	1074.00	0.108	1.631
37	1161.05	0.116	1.788	87	1203.23	0.219	3.082
38	906.63	0.074	1.140	88	NC	NC	NC
39	397.67	0.041	0.688	89	1200.53	0.162	2.438
40	939.46	0.075	1.111	90	1178.99	0.178	2.722
41	1047.95	0.096	1.490	91	1237.14	0.314	4.129
42	916.08	0.082	1.245	92	1152.09	0.118	1.945
43	1072.95	0.135	1.996	93	1637.01	0.298	7.299
44	885.20	0.078	1.191	94	1296.71	0.297	4.197
45	1074.81	0.113	1.653	95	1363.37	0.213	2.817
46	570.82	0.054	0.850	96	1225.93	0.160	2.624
47	699.33	0.047	0.760	97	1223.80	0.142	2.361
48	805.09	0.067	1.016	98	1244.57	0.159	2.453
49	867.77	0.081	1.257	99	1183.42	0.242	3.642
50	1108.31	0.125	1.840	100	1486.65	0.207	2.868

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Non-Convergence

Table A.2.2 Nonlinear Time History Results of Frame 'F2S2B2'

EQ	V (kN)	Δ (m)	MIDR (%)	EQ	V (kN)	Δ (m)	MIDR (%)
1	23.28	0.001	0.014	51	792.36	0.031	0.584
2	39.99	0.001	0.024	52	808.06	0.031	0.578
3	71.04	0.002	0.043	53	1088.33	0.048	0.889
4	114.44	0.004	0.075	54	1168.48	0.057	1.050
5	120.01	0.004	0.085	55	906.69	0.036	0.678
6	452.60	0.018	0.346	56	814.92	0.031	0.591
7	380.31	0.014	0.256	57	720.40	0.030	0.579
8	306.40	0.012	0.229	58	1046.57	0.046	0.882
9	338.89	0.012	0.234	59	914.03	0.036	0.671
10	488.58	0.019	0.359	60	679.52	0.028	0.538
11	286.28	0.010	0.183	61	795.61	0.031	0.607
12	347.59	0.013	0.234	62	1345.72	0.080	1.363
13	368.20	0.014	0.272	63	888.28	0.037	0.703
14	538.27	0.020	0.378	64	991.20	0.039	0.713
15	247.49	0.010	0.195	65	1226.60	0.070	1.205
16	297.54	0.010	0.182	66	1288.11	0.077	1.337
17	546.06	0.021	0.399	67	983.28	0.040	0.742
18	201.38	0.008	0.158	68	1163.99	0.066	1.183
19	543.27	0.021	0.390	69	1214.42	0.067	1.184
20	350.00	0.012	0.230	70	1141.30	0.058	1.108
21	927.11	0.038	0.718	71	1100.33	0.048	0.893
22	617.15	0.024	0.448	72	853.37	0.035	0.656
23	706.78	0.029	0.554	73	1196.97	0.056	1.008
24	538.15	0.020	0.376	74	1279.26	0.068	1.254
25	516.98	0.020	0.389	75	1048.73	0.053	1.027
26	647.34	0.025	0.471	76	1075.59	0.045	0.836
27	825.10	0.032	0.602	77	1064.19	0.042	0.763
28	665.75	0.026	0.488	78	1221.40	0.066	1.191
29	547.78	0.021	0.394	79	1057.91	0.047	0.901
30	669.58	0.027	0.514	80	1335.95	0.071	1.247
31	642.74	0.025	0.460	81	1271.51	0.070	1.218
32	862.43	0.035	0.679	82	1176.23	0.049	0.865
33	829.93	0.034	0.647	83	1243.29	0.080	1.341
34	687.25	0.027	0.519	84	1239.80	0.080	1.428
35	566.63	0.022	0.425	85	1291.20	0.072	1.240
36	995.15	0.041	0.772	86	1047.84	0.045	0.834
37	557.92	0.021	0.392	87	1212.01	0.049	0.877
38	979.46	0.041	0.767	88	1186.31	0.06	1.02
39	1002.13	0.046	0.894	89	1372.74	0.094	1.588
40	846.80	0.033	0.609	90	1269.03	0.076	1.334
41	684.58	0.026	0.503	91	1208.67	0.055	0.983
42	914.89	0.038	0.714	92	1179.09	0.072	1.358
43	602.16	0.023	0.428	93	1285.09	0.080	1.391
44	830.46	0.033	0.614	94	1454.88	0.137	2.346
45	708.40	0.027	0.512	95	1281.76	0.087	1.558
46	931.86	0.039	0.738	96	1373.80	0.105	1.759
47	771.01	0.033	0.647	97	1374.35	0.097	1.634
48	1000.21	0.044	0.852	98	1234.43	0.079	1.418
49	1085.81	0.046	0.861	99	1220.92	0.080	1.453
50	758.29	0.029	0.540	100	1400.10	0.169	2.854

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Non-Convergence

Table A.2.3 Nonlinear Time History Results of Frame ‘F3S2B’

EQ	V (kN)	Δ (m)	MIDR (%)	EQ	V (kN)	Δ (m)	MIDR (%)
1	33.57	0.001	0.019	51	1066.37	0.077	1.063
2	41.37	0.002	0.028	52	1296.88	0.121	1.573
3	128.68	0.007	0.094	53	706.22	0.047	0.656
4	100.95	0.005	0.069	54	1255.34	0.093	1.245
5	105.41	0.006	0.084	55	1088.94	0.071	0.977
6	281.78	0.016	0.214	56	1374.16	0.133	1.703
7	404.58	0.022	0.303	57	871.47	0.059	0.821
8	393.57	0.023	0.316	58	1275.90	0.124	1.616
9	538.20	0.032	0.436	59	1185.95	0.078	1.068
10	465.75	0.028	0.392	60	745.42	0.046	0.639
11	342.00	0.019	0.264	61	830.01	0.053	0.724
12	423.34	0.023	0.324	62	1152.33	0.084	1.153
13	546.95	0.033	0.452	63	1112.13	0.078	1.073
14	801.82	0.049	0.685	64	1104.49	0.074	1.027
15	249.34	0.013	0.185	65	916.18	0.082	1.134
16	550.11	0.032	0.449	66	1327.33	0.145	1.822
17	829.64	0.052	0.721	67	1273.86	0.109	1.433
18	533.69	0.029	0.402	68	1244.78	0.111	1.457
19	908.29	0.057	0.795	69	1313.11	0.109	1.420
20	805.01	0.048	0.665	70	1351.56	0.101	1.336
21	937.09	0.060	0.830	71	1140.45	0.088	1.209
22	922.03	0.057	0.788	72	1107.46	0.072	0.999
23	466.76	0.026	0.365	73	1262.43	0.121	1.585
24	361.50	0.022	0.303	74	1264.80	0.140	1.805
25	729.14	0.044	0.617	75	1398.44	0.135	1.728
26	1124.82	0.085	1.161	76	972.87	0.071	0.982
27	883.37	0.067	0.930	77	1231.08	0.078	1.066
28	817.28	0.048	0.657	78	1389.46	0.146	1.866
29	916.31	0.056	0.777	79	1321.13	0.137	1.760
30	310.75	0.020	0.284	80	1570.40	0.232	2.840
31	799.60	0.048	0.662	81	1464.85	0.164	2.072
32	1061.71	0.075	1.032	82	1346.85	0.222	2.688
33	784.75	0.057	0.798	83	1508.51	0.263	3.185
34	786.47	0.045	0.629	84	1180.81	0.105	1.408
35	805.69	0.047	0.651	85	1340.12	0.153	1.869
36	910.45	0.069	0.955	86	1096.25	0.073	1.023
37	1013.58	0.065	0.899	87	1424.82	0.163	2.063
38	864.66	0.057	0.786	88	1410.11	0.19	2.40
39	728.52	0.058	0.812	89	1396.07	0.176	2.212
40	1179.88	0.083	1.138	90	1387.51	0.140	1.785
41	1119.65	0.085	1.165	91	1458.20	0.199	2.450
42	1128.94	0.093	1.260	92	1192.00	0.119	1.561
43	1197.05	0.087	1.187	93	1495.66	0.146	1.839
44	971.89	0.062	0.863	94	1603.11	0.352	4.197
45	1011.82	0.068	0.940	95	1381.29	0.140	1.721
46	931.66	0.065	0.903	96	1365.12	0.133	1.754
47	817.86	0.053	0.733	97	1324.87	0.179	2.248
48	1159.64	0.090	1.212	98	1380.60	0.181	2.288
49	1069.47	0.080	1.104	99	1560.18	0.242	2.947
50	1152.64	0.075	1.028	100	1489.12	0.312	3.839

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Non-Convergence

Table A.2.4 Nonlinear Time History Results of Frame ‘F5S2B’

EQ	V (kN)	Δ (m)	MIDR (%)	EQ	V (kN)	Δ (m)	MIDR (%)
1	25.55	0.002	0.016	51	810.07	0.154	1.596
2	31.62	0.003	0.027	52	760.46	0.161	1.548
3	155.26	0.015	0.132	53	461.82	0.061	0.534
4	68.95	0.006	0.053	54	NC	NC	NC
5	148.85	0.013	0.110	55	737.99	0.098	0.850
6	134.66	0.012	0.115	56	739.85	0.267	5.421
7	329.58	0.036	0.338	57	614.24	0.081	0.722
8	453.08	0.056	0.500	58	778.59	0.162	1.656
9	363.57	0.046	0.402	59	898.08	0.359	4.363
10	248.65	0.033	0.288	60	751.56	0.099	0.940
11	236.52	0.025	0.220	61	716.30	0.106	0.986
12	442.45	0.055	0.491	62	750.88	0.153	1.482
13	718.51	0.098	0.892	63	797.40	0.206	2.171
14	791.81	0.115	1.139	64	826.49	0.146	1.497
15	151.74	0.014	0.120	65	532.78	0.086	0.761
16	343.69	0.042	0.383	66	770.08	0.152	1.479
17	570.30	0.072	0.646	67	809.18	0.202	2.201
18	324.73	0.037	0.324	68	746.24	0.131	1.261
19	742.31	0.120	1.119	69	855.03	0.182	2.024
20	855.11	0.150	1.608	70	862.53	0.252	2.797
21	576.83	0.072	0.644	71	696.66	0.102	0.920
22	743.13	0.093	0.869	72	796.02	0.111	1.076
23	381.19	0.045	0.407	73	855.82	0.219	2.336
24	218.81	0.023	0.204	74	796.32	0.140	1.374
25	603.44	0.069	0.651	75	826.54	0.234	2.500
26	770.24	0.116	1.122	76	810.26	0.119	1.215
27	600.93	0.078	0.673	77	916.71	0.728	7.923
28	782.93	0.122	1.215	78	883.35	0.176	2.045
29	775.44	0.117	1.142	79	746.24	0.152	1.488
30	152.59	0.018	0.153	80	783.94	0.336	3.344
31	693.13	0.082	0.773	81	NC	NC	NC
32	672.52	0.078	0.720	82	782.19	0.306	3.466
33	337.24	0.046	0.416	83	767.52	0.229	2.354
34	437.81	0.048	0.445	84	790.03	0.123	1.190
35	662.69	0.093	0.818	85	865.94	0.221	2.421
36	504.70	0.063	0.561	86	839.42	0.187	2.010
37	776.66	0.161	1.765	87	850.02	0.289	2.416
38	748.79	0.107	0.997	88	815.53	0.20	2.10
39	360.44	0.032	0.359	89	902.91	0.241	3.039
40	760.11	0.106	1.000	90	754.26	0.167	1.605
41	734.19	0.140	1.289	91	815.41	0.342	3.635
42	460.37	0.070	0.609	92	849.62	0.160	1.718
43	790.87	0.143	1.443	93	883.28	0.301	3.457
44	797.80	0.146	1.501	94	788.56	0.258	2.615
45	802.79	0.127	1.291	95	879.95	0.253	2.686
46	347.13	0.041	0.358	96	795.68	0.172	1.611
47	675.01	0.086	0.792	97	811.34	0.121	1.155
48	752.46	0.097	0.888	98	828.77	0.179	1.756
49	715.92	0.120	1.103	99	840.77	0.200	2.207
50	859.15	0.162	1.714	100	810.96	0.280	6.419

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Non-Convergence

Table A.2.5 Nonlinear Time History Results of Frame 'F5S4B'

EQ	V (kN)	Δ (m)	MIDR (%)	EQ	V (kN)	Δ (m)	MIDR (%)
1	124.99	0.005	0.033	51	3373.82	0.211	1.550
2	163.52	0.006	0.040	52	3116.47	0.182	1.257
3	490.47	0.022	0.140	53	2022.99	0.088	0.577
4	238.49	0.009	0.058	54	3320.32	0.237	1.724
5	313.78	0.013	0.080	55	3110.88	0.158	1.087
6	366.47	0.013	0.102	56	3579.28	0.258	1.927
7	721.75	0.033	0.212	57	2784.09	0.149	1.020
8	1381.58	0.066	0.443	58	3393.53	0.209	1.528
9	1520.12	0.082	0.528	59	3943.35	0.430	3.219
10	701.02	0.037	0.238	60	2301.41	0.123	0.794
11	880.01	0.037	0.253	61	3053.80	0.147	1.004
12	1797.30	0.085	0.581	62	3102.38	0.153	1.071
13	2468.96	0.128	0.846	63	3309.03	0.280	1.965
14	2868.41	0.153	1.051	64	3042.21	0.161	1.085
15	698.00	0.030	0.203	65	2811.90	0.116	0.768
16	1221.43	0.051	0.357	66	2863.79	0.175	1.222
17	1897.86	0.098	0.654	67	3214.54	0.255	1.837
18	771.17	0.039	0.257	68	3311.79	0.203	1.465
19	2440.39	0.128	0.852	69	3740.70	0.271	1.917
20	3591.12	0.233	1.737	70	3761.34	0.299	2.230
21	2188.97	0.098	0.665	71	1787.35	0.099	0.660
22	3031.96	0.162	1.146	72	3475.70	0.206	1.469
23	1465.98	0.069	0.467	73	3717.68	0.246	1.879
24	1172.14	0.049	0.343	74	3658.31	0.191	1.356
25	1782.08	0.084	0.571	75	3048.15	0.263	1.820
26	2861.24	0.143	0.986	76	3224.93	0.147	0.983
27	2178.04	0.106	0.693	77	3844.41	0.513	3.656
28	3415.26	0.195	1.373	78	3761.03	0.230	1.748
29	2914.01	0.167	1.171	79	2397.90	0.188	1.312
30	573.87	0.011	0.129	80	3595.29	0.389	2.666
31	2740.49	0.142	0.979	81	3698.16	0.695	4.516
32	2445.04	0.118	0.810	82	3459.33	0.329	2.300
33	994.83	0.039	0.293	83	3242.10	0.241	1.754
34	2410.92	0.117	0.793	84	2703.54	0.163	1.098
35	1421.61	0.070	0.464	85	3512.86	0.291	2.042
36	1825.58	0.097	0.638	86	3202.42	0.237	1.711
37	3323.27	0.216	1.565	87	3601.51	0.263	1.941
38	2887.27	0.159	1.102	88	3869.50	0.30	2.19
39	1268.35	0.026	0.335	89	4144.83	0.286	2.160
40	3139.68	0.171	1.198	90	3176.78	0.215	1.496
41	2428.04	0.122	0.803	91	3578.07	0.393	2.705
42	1062.48	0.059	0.398	92	3300.56	0.192	1.382
43	2692.77	0.140	0.963	93	3544.77	0.315	2.173
44	3223.66	0.245	1.713	94	3850.06	0.367	2.558
45	3154.14	0.177	1.251	95	3893.19	0.372	2.713
46	1272.90	0.041	0.297	96	3181.32	0.208	1.493
47	2714.71	0.119	0.778	97	3742.09	0.189	1.318
48	2978.48	0.125	0.900	98	3288.00	0.256	1.829
49	2580.58	0.156	1.028	99	3466.58	0.238	1.728
50	3253.42	0.181	1.357	100	3784.12	0.274	2.063

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Non-Convergence

Table A.2.6 Nonlinear Time History Results of Frame 'F5S7B'

EQ	V (kN)	Δ (m)	MIDR (%)	EQ	V (kN)	Δ (m)	MIDR (%)
1	74.97	0.002	0.018	51	3026.34	0.120	1.240
2	77.07	0.002	0.019	52	2876.44	0.159	1.662
3	471.24	0.013	0.120	53	1458.64	0.051	0.487
4	246.77	0.006	0.057	54	3183.84	0.122	1.277
5	485.19	0.013	0.123	55	2502.27	0.079	0.839
6	656.16	0.016	0.154	56	3092.60	0.229	2.499
7	1082.10	0.034	0.316	57	2042.31	0.068	0.672
8	1126.69	0.033	0.312	58	NC	NC	NC
9	1615.76	0.056	0.516	59	3464.15	0.223	2.819
10	1353.58	0.050	0.448	60	2301.03	0.083	0.816
11	964.95	0.029	0.270	61	2431.65	0.069	0.673
12	1385.46	0.043	0.406	62	3015.14	0.168	1.795
13	2104.10	0.064	0.646	63	3473.29	0.211	4.550
14	2420.96	0.076	0.761	64	2940.03	0.123	1.244
15	537.99	0.015	0.142	65	1518.14	0.056	0.517
16	1192.20	0.037	0.336	66	2930.41	0.130	1.323
17	1481.60	0.037	0.371	67	3183.49	0.179	1.888
18	1396.39	0.047	0.430	68	2850.93	0.121	1.177
19	2565.55	0.089	0.894	69	3232.20	0.195	2.026
20	2651.16	0.086	0.867	70	3320.10	0.207	2.301
21	2135.21	0.073	0.700	71	2530.84	0.114	1.140
22	2408.91	0.083	0.827	72	2468.70	0.089	0.852
23	1239.58	0.041	0.378	73	NC	NC	NC
24	832.63	0.024	0.228	74	2967.98	0.158	1.627
25	1577.29	0.046	0.450	75	3203.62	0.205	4.706
26	2896.31	0.110	1.109	76	2705.46	0.109	1.096
27	2024.39	0.081	0.748	77	3283.98	0.370	5.382
28	2289.41	0.069	0.694	78	2990.78	0.194	2.119
29	2436.32	0.087	0.861	79	2951.29	0.187	2.050
30	577.92	0.018	0.161	80	NC	NC	NC
31	3008.16	0.115	1.215	81	NC	NC	NC
32	2590.39	0.090	0.909	82	NC	NC	NC
33	1375.45	0.049	0.448	83	3059.42	0.214	2.297
34	1540.24	0.046	0.434	84	3183.53	0.111	1.122
35	1831.68	0.062	0.591	85	3144.56	0.186	1.891
36	2122.64	0.073	0.708	86	3121.22	0.139	1.783
37	3138.30	0.128	1.372	87	NC	NC	NC
38	2476.06	0.090	0.897	88	3300.04	0.20	2.21
39	968.07	0.037	0.367	89	2902.63	0.200	2.772
40	2459.76	0.087	0.862	90	3201.67	0.182	1.892
41	2956.84	0.132	1.319	91	NC	NC	NC
42	2019.85	0.079	0.749	92	3266.16	0.136	1.431
43	3113.67	0.145	1.543	93	3381.59	0.284	3.360
44	2694.91	0.100	1.026	94	NC	NC	NC
45	3033.14	0.117	1.243	95	3278.57	0.190	2.108
46	1077.52	0.046	0.403	96	3201.47	0.158	1.600
47	1542.00	0.046	0.439	97	3049.22	0.138	1.436
48	2215.75	0.071	0.674	98	3263.06	0.180	1.969
49	2129.46	0.079	0.749	99	NC	NC	NC
50	3051.84	0.152	1.622	100	3535.19	0.191	2.262

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Non-Convergence

Table A.2.7 Nonlinear Time History Results of Frame ‘F8S3B’

EQ	V (kN)	Δ (m)	MIDR (%)	EQ	V (kN)	Δ (m)	MIDR (%)
1	118.13	0.005	0.022	51	4600.50	0.281	1.231
2	100.94	0.004	0.019	52	4598.02	0.241	1.210
3	501.60	0.028	0.115	53	3304.80	0.148	0.591
4	257.42	0.007	0.037	54	3869.35	0.232	0.950
5	309.41	0.013	0.058	55	3693.61	0.240	1.085
6	617.96	0.023	0.138	56	4098.09	0.333	1.660
7	974.15	0.048	0.230	57	3780.23	0.207	0.829
8	1775.67	0.087	0.345	58	3808.10	0.310	1.473
9	2569.86	0.135	0.545	59	4476.82	0.643	2.515
10	829.65	0.050	0.241	60	1852.23	0.104	0.450
11	1077.32	0.043	0.166	61	3611.02	0.202	0.794
12	2654.56	0.138	0.540	62	3775.11	0.204	0.883
13	1045.11	0.072	0.334	63	4267.58	0.268	1.314
14	3445.02	0.170	0.678	64	4462.81	0.368	1.544
15	834.08	0.045	0.182	65	4013.92	0.160	0.694
16	2582.02	0.106	0.416	66	4084.59	0.242	1.342
17	2533.61	0.164	0.662	67	4633.17	0.252	1.233
18	1185.04	0.053	0.232	68	4617.02	0.332	1.458
19	3376.85	0.195	0.753	69	4427.92	0.328	1.533
20	4379.30	0.425	1.807	70	4450.23	0.325	1.383
21	3062.67	0.162	0.654	71	3014.36	0.147	0.721
22	3906.16	0.191	0.781	72	3745.57	0.293	1.441
23	1357.01	0.076	0.298	73	3937.03	0.477	2.107
24	1353.92	0.062	0.251	74	3527.50	0.181	1.079
25	2676.81	0.166	0.704	75	3960.46	0.285	1.607
26	3589.40	0.220	1.032	76	3313.95	0.187	0.863
27	3148.03	0.147	0.571	77	NC	NC	NC
28	4166.46	0.382	1.755	78	4773.08	0.295	1.361
29	3961.45	0.372	1.701	79	2916.48	0.184	0.996
30	652.40	0.013	0.148	80	4750.06	0.346	1.966
31	3747.38	0.177	0.706	81	4903.73	0.648	3.826
32	3617.15	0.265	1.313	82	NC	NC	NC
33	1125.96	0.041	0.321	83	3705.77	0.268	1.705
34	1941.66	0.106	0.462	84	3562.31	0.182	1.024
35	2866.72	0.131	0.556	85	4642.77	0.231	1.330
36	2840.09	0.146	0.614	86	3334.67	0.281	1.363
37	3946.81	0.281	1.256	87	4867.80	0.390	1.886
38	3226.28	0.175	0.798	88	4652.91	0.38	1.62
39	1276.43	0.027	0.321	89	4504.00	0.323	1.556
40	4446.53	0.475	1.991	90	4571.48	0.270	1.167
41	3164.67	0.246	1.145	91	4580.67	0.450	2.462
42	2511.33	0.076	0.582	92	4463.28	0.256	1.208
43	3501.72	0.264	1.229	93	3777.39	0.242	1.423
44	4005.05	0.268	1.247	94	5241.55	0.436	2.003
45	3890.26	0.276	1.159	95	4353.65	0.411	1.899
46	1501.01	0.061	0.396	96	3817.77	0.194	1.090
47	3770.46	0.192	0.760	97	5031.11	0.341	1.507
48	4465.53	0.211	0.836	98	5309.55	0.507	2.386
49	3721.53	0.174	0.704	99	4743.19	0.294	1.657
50	3668.73	0.272	1.167	100	NC	NC	NC

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Non-Convergence

A.3 EQUIVALENT SDOF ANALYSIS RESULTS

Table A.3.1 Results of SDOF Analyses of Frame 'F2S2B' (MULTI Idealization Method)

EQ	MULTI				
	μ_{MULTI}	R_{MULTI}	V (kN)	Δ (m)	MIDR (%)
1	0.041	0.041	39.22	0.002	0.035
2	0.041	0.041	39.34	0.002	0.035
3	0.198	0.228	160.33	0.011	0.162
4	0.082	0.082	73.60	0.005	0.069
5	0.191	0.193	155.53	0.011	0.157
6	0.278	0.297	226.79	0.015	0.225
7	0.460	0.499	372.92	0.025	0.369
8	0.536	0.515	432.38	0.029	0.430
9	1.088	1.061	751.02	0.060	0.879
10	0.932	0.863	677.05	0.051	0.747
11	0.407	0.373	331.62	0.022	0.327
12	0.592	0.632	475.98	0.033	0.475
13	1.057	1.095	737.43	0.058	0.852
14	0.889	1.005	652.37	0.049	0.712
15	0.234	0.220	189.46	0.013	0.191
16	0.541	0.511	436.00	0.030	0.434
17	0.667	0.823	525.37	0.037	0.535
18	0.709	0.678	549.34	0.039	0.568
19	0.901	1.037	659.44	0.050	0.722
20	1.117	0.958	763.64	0.061	0.904
21	0.881	0.990	648.12	0.048	0.706
22	1.304	1.319	843.28	0.072	1.066
23	0.745	0.653	570.08	0.041	0.597
24	0.418	0.440	340.41	0.023	0.336
25	0.858	1.087	634.86	0.047	0.688
26	1.561	1.736	944.46	0.086	1.283
27	1.477	1.439	912.57	0.081	1.213
28	1.034	1.303	727.24	0.057	0.832
29	1.639	1.380	972.82	0.090	1.348
30	0.241	0.261	195.57	0.013	0.196
31	1.281	0.953	833.80	0.070	1.047
32	1.467	2.032	908.70	0.081	1.205
33	0.870	0.872	641.58	0.048	0.697
34	0.973	1.165	699.12	0.053	0.780
35	0.818	0.969	611.85	0.045	0.655
36	1.437	1.562	896.75	0.079	1.179
37	1.908	1.942	1052.54	0.105	1.557
38	1.277	1.189	832.22	0.070	1.043
39	0.723	0.816	557.56	0.040	0.580
40	1.489	1.490	917.31	0.082	1.223
41	1.744	1.979	1006.14	0.096	1.431
42	1.551	2.245	940.89	0.085	1.275
43	2.507	2.381	1126.89	0.138	1.939
44	1.494	1.298	919.28	0.082	1.227
45	1.436	1.418	896.64	0.079	1.179
46	0.981	1.044	703.47	0.054	0.787
47	0.863	0.887	637.84	0.047	0.692
48	0.979	1.192	702.57	0.054	0.786
49	1.382	1.761	875.13	0.076	1.133
50	2.053	1.663	1083.11	0.113	1.660

EQ	MULTI				
	μ_{MULTI}	R_{MULTI}	V (kN)	Δ (m)	MIDR (%)
51	1.256	1.013	822.96	0.069	1.024
52	2.921	3.257	1167.97	0.161	2.195
53	0.810	0.779	607.61	0.045	0.649
54	1.863	1.523	1040.77	0.102	1.523
55	1.445	1.510	900.18	0.079	1.186
56	3.460	2.367	1205.05	0.190	2.543
57	1.072	1.200	744.09	0.059	0.865
58	2.735	2.633	1149.81	0.150	2.080
59	3.261	1.909	1196.90	0.179	2.412
60	0.971	0.915	698.39	0.053	0.779
61	0.884	0.845	649.70	0.049	0.708
62	2.915	1.911	1167.35	0.160	2.192
63	1.864	1.249	1041.11	0.103	1.524
64	1.971	1.602	1067.20	0.108	1.603
65	0.870	0.999	641.59	0.048	0.697
66	2.727	4.106	1149.01	0.150	2.075
67	2.762	3.172	1152.73	0.152	2.097
68	1.969	2.659	1066.81	0.108	1.602
69	3.179	3.343	1192.20	0.175	2.359
70	3.421	2.376	1203.54	0.188	2.517
71	2.047	2.384	1081.86	0.113	1.656
72	1.633	1.725	970.74	0.090	1.343
73	3.422	2.582	1203.58	0.188	2.518
74	2.516	2.995	1128.07	0.138	1.945
75	3.035	2.701	1180.48	0.167	2.267
76	1.313	1.194	846.95	0.072	1.074
77	4.870	1.898	1193.37	0.268	3.530
78	2.840	2.715	1160.35	0.156	2.146
79	3.264	3.623	1197.02	0.179	2.413
80	4.517	5.326	1198.68	0.248	3.279
81	5.012	3.309	1190.65	0.276	3.631
82	4.149	3.801	1211.18	0.228	3.020
83	3.957	4.527	1214.13	0.218	2.883
84	2.102	2.397	1091.15	0.116	1.693
85	2.970	4.469	1173.46	0.163	2.226
86	1.783	1.373	1017.71	0.098	1.461
87	4.250	4.766	1207.11	0.234	3.092
88	NC	NC	NC	NC	NC
89	2.661	3.137	1143.68	0.146	2.035
90	3.292	3.983	1198.30	0.181	2.432
91	5.533	4.390	1184.08	0.304	3.992
92	2.186	2.659	1101.50	0.120	1.747
93	4.184	2.973	1210.07	0.230	3.045
94	6.056	4.398	1184.56	0.333	4.359
95	3.600	2.643	1210.34	0.198	2.636
96	3.426	2.347	1203.73	0.188	2.521
97	2.877	4.362	1163.44	0.158	2.168
98	3.198	2.999	1193.38	0.176	2.371
99	4.851	4.123	1193.29	0.267	3.516
100	4.443	5.348	1199.25	0.244	3.228

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Non-Convergence

Table A.3.2 Results of SDOF Analyses of Frame 'F2S2B'

(ATC Idealization Method)

EQ	ATC					EQ	ATC				
	μ_{ATC}	R_{ATC}	V (kN)	Δ (m)	MIDR (%)		μ_{ATC}	R_{ATC}	V (kN)	Δ (m)	MIDR (%)
1	0.041	0.041	39.23	0.002	0.035	51	1.013	1.013	718.07	0.074	0.814
2	0.041	0.041	39.35	0.002	0.035	52	2.673	3.257	1144.77	0.170	2.043
3	0.228	0.228	184.59	0.013	0.186	53	0.779	0.779	589.70	0.046	0.624
4	0.082	0.082	73.61	0.007	0.069	54	1.801	1.523	1023.10	0.098	1.475
5	0.193	0.193	156.55	0.013	0.158	55	1.693	1.510	990.78	0.073	1.391
6	0.296	0.296	242.07	0.017	0.240	56	3.268	2.367	1197.20	0.202	2.416
7	0.499	0.499	404.06	0.027	0.401	57	1.188	1.200	794.17	0.076	0.966
8	0.515	0.515	415.94	0.033	0.413	58	1.979	2.634	1068.99	0.126	1.609
9	1.064	1.062	740.55	0.077	0.858	59	2.876	1.909	1163.36	0.173	2.167
10	0.864	0.864	638.19	0.067	0.692	60	0.915	0.915	667.29	0.062	0.733
11	0.373	0.373	304.54	0.029	0.301	61	0.845	0.845	627.51	0.061	0.677
12	0.632	0.632	504.93	0.038	0.507	62	3.153	1.911	1190.62	0.196	2.342
13	1.101	1.095	756.43	0.059	0.890	63	1.230	1.249	811.98	0.087	1.002
14	1.005	1.005	714.47	0.055	0.807	64	1.829	1.602	1031.26	0.105	1.497
15	0.220	0.220	177.89	0.016	0.180	65	0.999	0.999	711.81	0.047	0.802
16	0.511	0.511	413.03	0.037	0.410	66	2.526	4.106	1129.37	0.140	1.951
17	0.822	0.822	614.60	0.036	0.659	67	2.695	3.173	1146.60	0.166	2.056
18	0.678	0.678	531.84	0.045	0.544	68	2.331	2.659	1107.68	0.141	1.829
19	1.037	1.036	728.72	0.053	0.835	69	2.304	3.342	1106.29	0.181	1.814
20	0.958	0.958	691.77	0.062	0.768	70	2.554	2.376	1133.01	0.163	1.969
21	0.990	0.990	708.16	0.060	0.795	71	1.662	2.384	980.77	0.119	1.367
22	1.171	1.319	786.66	0.085	0.951	72	2.054	1.725	1083.21	0.115	1.661
23	0.653	0.653	517.30	0.043	0.524	73	2.768	2.582	1153.27	0.174	2.100
24	0.440	0.440	357.38	0.022	0.353	74	2.254	2.994	1105.45	0.131	1.787
25	1.090	1.086	751.78	0.053	0.881	75	2.761	2.701	1152.58	0.159	2.096
26	1.396	1.736	880.84	0.094	1.145	76	1.209	1.194	803.24	0.089	0.984
27	1.445	1.439	899.90	0.089	1.186	77	4.121	1.898	1211.94	0.241	3.000
28	1.159	1.303	781.60	0.068	0.940	78	3.306	2.714	1198.92	0.157	2.441
29	1.545	1.381	938.82	0.103	1.270	79	2.660	3.623	1143.64	0.165	2.035
30	0.261	0.261	212.38	0.017	0.212	80	4.761	5.327	1194.83	0.271	3.452
31	0.953	0.953	689.20	0.081	0.764	81	3.956	3.309	1214.13	0.246	2.882
32	1.782	2.032	1017.60	0.101	1.461	82	3.827	3.802	1213.78	0.211	2.793
33	0.872	0.872	642.72	0.049	0.699	83	3.694	4.528	1212.32	0.205	2.700
34	1.174	1.164	788.08	0.063	0.954	84	2.118	2.397	1093.35	0.113	1.704
35	0.969	0.969	697.29	0.041	0.777	85	2.751	4.468	1151.47	0.151	2.090
36	1.585	1.562	953.24	0.100	1.303	86	1.473	1.374	911.02	0.100	1.210
37	1.446	1.942	900.64	0.123	1.187	87	3.659	4.766	1211.69	0.219	2.676
38	1.206	1.189	801.98	0.069	0.982	88	NC	NC	NC	NC	NC
39	0.816	0.816	610.96	0.040	0.654	89	2.164	3.137	1099.44	0.137	1.734
40	1.536	1.490	935.59	0.081	1.263	90	3.086	3.984	1185.77	0.183	2.300
41	1.659	1.978	979.60	0.099	1.364	91	5.410	4.390	1185.03	0.304	3.908
42	1.413	2.244	887.35	0.094	1.159	92	2.211	2.658	1102.95	0.136	1.762
43	2.152	2.381	1097.94	0.120	1.726	93	3.418	2.973	1203.39	0.214	2.515
44	1.398	1.299	881.56	0.097	1.146	94	5.194	4.400	1186.12	0.306	3.758
45	1.255	1.418	822.51	0.085	1.024	95	3.550	2.644	1208.46	0.196	2.602
46	1.044	1.043	731.98	0.053	0.841	96	4.014	2.347	1213.79	0.234	2.924
47	0.887	0.887	651.28	0.050	0.711	97	3.239	4.362	1195.79	0.183	2.397
48	1.212	1.192	804.46	0.066	0.987	98	3.377	2.998	1201.81	0.158	2.488
49	1.373	1.761	871.48	0.084	1.125	99	4.397	4.124	1200.25	0.252	3.196
50	2.044	1.663	1081.38	0.119	1.654	100	4.319	5.347	1202.49	0.235	3.141

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.3 Results of SDOF Analyses of Frame 'F2S2B'

(FEMA Idealization Method)

EQ	FEMA					EQ	FEMA				
	μ_{FEMA}	R_{FEMA}	V (kN)	Δ (m)	MIDR (%)		μ_{FEMA}	R_{FEMA}	V (kN)	Δ (m)	MIDR (%)
1	0.031	0.031	37.45	0.002	0.033	51	1.066	1.063	862.64	0.074	1.107
2	0.032	0.032	38.53	0.002	0.034	52	2.442	2.665	1186.50	0.170	2.305
3	0.182	0.182	186.68	0.013	0.188	53	0.660	0.660	622.98	0.046	0.671
4	0.097	0.097	104.04	0.007	0.102	54	1.405	1.315	1016.94	0.098	1.459
5	0.183	0.183	187.96	0.013	0.189	55	1.044	1.092	850.86	0.073	1.082
6	0.238	0.238	245.89	0.017	0.244	56	2.893	2.240	1211.82	0.202	2.681
7	0.388	0.388	398.16	0.027	0.395	57	1.095	1.191	877.64	0.076	1.138
8	0.478	0.478	486.00	0.033	0.485	58	1.812	3.175	1106.70	0.126	1.810
9	1.104	1.262	881.97	0.077	1.147	59	2.479	1.781	1189.97	0.173	2.335
10	0.954	0.954	803.24	0.067	0.984	60	0.890	0.890	768.41	0.062	0.914
11	0.416	0.416	425.73	0.029	0.423	61	0.868	0.868	756.28	0.061	0.890
12	0.550	0.550	542.49	0.038	0.559	62	2.818	2.222	1209.28	0.196	2.617
13	0.847	0.847	744.74	0.059	0.867	63	1.250	1.236	953.10	0.087	1.303
14	0.791	0.791	713.66	0.055	0.805	64	1.507	1.403	1052.98	0.105	1.558
15	0.235	0.235	243.22	0.016	0.241	65	0.677	0.677	635.05	0.047	0.688
16	0.536	0.536	532.19	0.037	0.544	66	2.008	3.101	1131.82	0.140	1.963
17	0.516	0.516	517.97	0.036	0.524	67	2.382	2.784	1178.75	0.166	2.257
18	0.647	0.647	613.52	0.045	0.658	68	2.028	2.354	1135.10	0.141	1.979
19	0.759	0.759	693.73	0.053	0.772	69	2.604	2.394	1198.62	0.181	2.437
20	0.892	0.892	769.36	0.062	0.916	70	2.335	2.149	1172.35	0.163	2.220
21	0.860	0.860	751.85	0.060	0.881	71	1.712	2.694	1100.20	0.119	1.738
22	1.222	1.199	939.99	0.085	1.273	72	1.653	1.550	1090.26	0.115	1.689
23	0.610	0.610	586.43	0.043	0.620	73	2.499	2.884	1191.49	0.174	2.351
24	0.309	0.309	319.02	0.022	0.315	74	1.883	2.045	1113.29	0.131	1.863
25	0.762	0.762	695.21	0.053	0.774	75	2.285	2.371	1165.41	0.159	2.180
26	1.352	1.688	996.78	0.094	1.407	76	1.277	1.250	965.18	0.089	1.330
27	1.275	1.246	964.52	0.089	1.329	77	3.453	1.833	1200.61	0.241	3.181
28	0.969	0.969	811.38	0.068	1.001	78	2.253	2.003	1161.61	0.157	2.155
29	1.482	1.387	1045.05	0.103	1.535	79	2.361	3.399	1175.93	0.165	2.240
30	0.244	0.244	253.01	0.017	0.250	80	3.882	5.029	1193.46	0.271	3.565
31	1.157	1.142	908.59	0.081	1.204	81	3.523	3.344	1198.82	0.246	3.243
32	1.447	1.639	1032.79	0.101	1.501	82	3.029	4.719	1213.86	0.211	2.801
33	0.710	0.710	658.43	0.049	0.721	83	2.946	4.718	1213.01	0.205	2.728
34	0.907	0.907	777.65	0.063	0.932	84	1.627	2.412	1084.74	0.113	1.666
35	0.581	0.581	565.56	0.041	0.591	85	2.173	3.341	1151.83	0.151	2.092
36	1.430	1.368	1026.63	0.100	1.485	86	1.431	1.349	1026.91	0.100	1.485
37	1.764	2.344	1104.28	0.123	1.776	87	3.140	4.348	1214.01	0.219	2.899
38	0.986	0.986	820.33	0.069	1.019	88	NC	NC	NC	NC	NC
39	0.569	0.569	556.82	0.040	0.578	89	1.970	2.592	1125.59	0.137	1.933
40	1.156	1.141	907.88	0.081	1.203	90	2.625	3.521	1199.80	0.183	2.455
41	1.422	1.708	1023.50	0.099	1.476	91	4.359	4.037	1184.14	0.304	3.987
42	1.350	1.536	996.19	0.094	1.405	92	1.954	2.025	1122.82	0.136	1.919
43	1.728	2.175	1101.74	0.120	1.749	93	3.073	2.929	1214.15	0.214	2.840
44	1.397	1.340	1013.82	0.097	1.451	94	4.391	5.014	1183.85	0.306	4.014
45	1.217	1.192	938.04	0.085	1.268	95	2.809	2.923	1208.84	0.196	2.609
46	0.754	0.754	690.49	0.053	0.766	96	3.354	2.600	1207.10	0.234	3.093
47	0.717	0.717	663.56	0.050	0.728	97	2.621	4.680	1199.59	0.183	2.452
48	0.947	0.947	799.46	0.066	0.977	98	2.266	3.391	1162.91	0.158	2.164
49	1.205	1.359	931.95	0.084	1.255	99	3.616	4.007	1198.20	0.252	3.326
50	1.702	1.515	1098.56	0.119	1.729	100	3.370	4.349	1204.77	0.235	3.106

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.4 Results of SDOF Analyses of Frame ‘F2S2B’

(75%V_y Idealization Method)

EQ	75%Vy					EQ	75%Vy				
	$\mu_{75\%Vy}$	$R_{75\%Vy}$	V (kN)	Δ (m)	MIDR (%)		$\mu_{75\%Vy}$	$R_{75\%Vy}$	V (kN)	Δ (m)	MIDR (%)
1	0.021	0.021	33.95	0.002	0.030	51	1.090	1.147	1039.15	0.102	1.519
2	0.027	0.027	44.47	0.003	0.040	52	2.036	1.800	1205.37	0.191	2.549
3	0.161	0.161	222.77	0.015	0.222	53	0.546	0.546	675.70	0.051	0.745
4	0.080	0.080	114.67	0.008	0.113	54	1.107	1.098	1046.87	0.104	1.541
5	0.156	0.156	216.25	0.015	0.216	55	1.001	1.001	994.55	0.094	1.401
6	0.165	0.165	229.12	0.015	0.228	56	2.510	2.041	1204.64	0.235	3.110
7	0.372	0.372	506.20	0.035	0.508	57	0.833	0.833	890.06	0.078	1.165
8	0.357	0.357	487.81	0.033	0.487	58	1.586	2.342	1147.19	0.149	2.060
9	0.845	0.845	898.28	0.079	1.182	59	2.034	1.603	1205.23	0.191	2.546
10	0.727	0.727	815.40	0.068	1.009	60	0.850	0.850	901.43	0.080	1.189
11	0.321	0.321	441.42	0.030	0.439	61	0.852	0.852	902.77	0.080	1.192
12	0.517	0.517	648.35	0.048	0.707	62	2.229	2.069	1213.57	0.209	2.772
13	0.680	0.680	781.29	0.064	0.940	63	1.762	1.514	1176.91	0.165	2.246
14	0.779	0.779	853.01	0.073	1.087	64	1.229	1.201	1089.96	0.115	1.688
15	0.144	0.144	198.17	0.013	0.199	65	0.564	0.564	693.44	0.053	0.771
16	0.404	0.404	537.70	0.038	0.552	66	2.109	1.912	1210.08	0.198	2.631
17	0.408	0.408	541.28	0.038	0.557	67	2.290	2.230	1214.17	0.215	2.845
18	0.622	0.622	738.72	0.058	0.855	68	1.468	1.665	1126.08	0.138	1.935
19	0.682	0.682	783.25	0.064	0.944	69	2.688	2.426	1198.28	0.252	3.324
20	0.752	0.752	833.43	0.070	1.046	70	2.246	1.836	1213.78	0.210	2.793
21	0.837	0.837	892.65	0.078	1.170	71	1.614	1.865	1151.33	0.151	2.089
22	0.959	0.959	971.20	0.090	1.344	72	1.061	1.059	1024.93	0.099	1.480
23	0.427	0.427	560.23	0.040	0.583	73	2.151	2.679	1211.79	0.202	2.680
24	0.276	0.276	380.65	0.026	0.377	74	1.345	1.531	1106.77	0.126	1.808
25	0.544	0.544	674.13	0.051	0.743	75	1.806	1.845	1184.85	0.169	2.293
26	1.212	1.386	1085.21	0.114	1.668	76	1.097	1.092	1042.24	0.103	1.527
27	0.927	0.927	951.38	0.087	1.299	77	3.458	1.918	1184.56	0.324	4.243
28	0.605	0.605	726.13	0.057	0.830	78	1.866	1.416	1192.25	0.175	2.359
29	0.994	0.994	990.96	0.093	1.392	79	2.033	2.919	1205.15	0.190	2.545
30	0.226	0.226	313.81	0.021	0.310	80	2.801	3.895	1194.62	0.262	3.460
31	1.361	1.302	1106.57	0.128	1.822	81	2.951	3.386	1190.01	0.276	3.641
32	1.115	1.110	1050.48	0.104	1.551	82	2.246	3.915	1213.78	0.210	2.792
33	0.535	0.535	665.85	0.050	0.731	83	2.258	4.315	1213.91	0.212	2.807
34	0.630	0.630	744.54	0.059	0.866	84	1.494	2.344	1131.84	0.140	1.963
35	0.525	0.525	656.00	0.049	0.717	85	1.653	2.284	1158.21	0.155	2.131
36	0.994	0.994	990.57	0.093	1.391	86	1.288	1.373	1102.07	0.121	1.752
37	1.590	1.963	1147.66	0.149	2.064	87	2.624	3.544	1198.75	0.246	3.247
38	1.028	1.028	1008.41	0.096	1.437	88	NC	NC	NC	NC	NC
39	0.385	0.385	519.23	0.036	0.526	89	1.654	1.814	1158.32	0.155	2.132
40	0.934	0.934	955.80	0.088	1.309	90	2.231	2.510	1213.60	0.209	2.774
41	1.303	1.279	1103.36	0.122	1.767	91	3.336	3.503	1182.94	0.313	4.096
42	0.982	0.982	984.36	0.092	1.375	92	1.356	1.951	1106.18	0.127	1.817
43	1.672	1.739	1161.08	0.157	2.151	93	2.668	2.692	1198.66	0.250	3.300
44	0.806	0.806	871.29	0.075	1.125	94	3.564	3.689	1184.54	0.334	4.370
45	1.452	1.360	1122.55	0.136	1.918	95	2.255	3.512	1213.87	0.211	2.803
46	0.496	0.496	627.17	0.046	0.677	96	2.431	2.995	1211.37	0.228	3.015
47	0.505	0.505	636.71	0.047	0.690	97	2.224	4.132	1213.51	0.208	2.766
48	0.709	0.709	802.78	0.066	0.983	98	1.889	4.083	1194.56	0.177	2.384
49	1.004	1.004	996.10	0.094	1.405	99	2.841	3.660	1193.35	0.266	3.507
50	1.471	1.612	1126.68	0.138	1.938	100	2.725	3.919	1196.25	0.255	3.369

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.5 Results of SDOF Analyses of Frame 'F2S2B2'

(MULTI Idealization Method)

EQ	MULTI					EQ	MULTI				
	μ_{MULTI}	R_{MULTI}	V (kN)	Δ (m)	MIDR (%)		μ_{MULTI}	R_{MULTI}	V (kN)	Δ (m)	MIDR (%)
1	0.020	0.020	26.09	0.001	0.016	51	0.684	0.677	710.67	0.027	0.516
2	0.037	0.037	44.76	0.001	0.030	52	0.764	0.809	790.16	0.030	0.576
3	0.067	0.067	74.77	0.003	0.052	53	0.969	0.842	958.28	0.038	0.730
4	0.106	0.106	117.33	0.004	0.081	54	1.318	1.333	1150.10	0.052	0.974
5	0.105	0.105	117.04	0.004	0.081	55	1.028	1.250	998.39	0.041	0.772
6	0.457	0.504	481.66	0.018	0.345	56	0.732	0.755	757.63	0.029	0.551
7	0.321	0.330	342.97	0.013	0.243	57	0.544	0.526	569.66	0.022	0.410
8	0.255	0.257	274.40	0.010	0.193	58	0.834	0.745	854.81	0.033	0.628
9	0.279	0.278	299.55	0.011	0.211	59	0.854	0.831	872.90	0.034	0.644
10	0.454	0.450	478.87	0.018	0.343	60	0.693	0.704	718.83	0.027	0.522
11	0.241	0.246	260.37	0.010	0.183	61	0.715	0.722	741.59	0.028	0.539
12	0.317	0.337	338.22	0.013	0.240	62	1.392	1.479	1170.44	0.055	1.023
13	0.316	0.313	337.37	0.013	0.239	63	0.922	0.950	925.03	0.037	0.695
14	0.407	0.407	431.04	0.016	0.308	64	0.868	0.847	883.91	0.034	0.654
15	0.268	0.273	287.95	0.011	0.203	65	1.742	1.813	1244.96	0.069	1.245
16	0.242	0.243	261.08	0.010	0.183	66	1.262	1.115	1131.26	0.050	0.936
17	0.453	0.457	477.45	0.018	0.342	67	1.100	1.149	1046.98	0.044	0.825
18	0.243	0.243	262.27	0.010	0.184	68	1.591	2.025	1222.81	0.063	1.155
19	0.530	0.606	555.14	0.021	0.399	69	1.425	1.395	1179.52	0.056	1.045
20	0.324	0.322	345.62	0.013	0.245	70	1.411	1.451	1175.83	0.056	1.036
21	0.832	0.817	853.31	0.033	0.627	71	1.014	0.923	989.03	0.040	0.762
22	0.550	0.550	575.65	0.022	0.415	72	0.674	0.646	699.95	0.027	0.508
23	0.662	0.665	688.28	0.026	0.499	73	1.358	1.460	1161.09	0.054	1.001
24	0.384	0.379	407.48	0.015	0.290	74	1.560	1.932	1215.62	0.062	1.136
25	0.481	0.494	505.94	0.019	0.363	75	1.389	1.368	1169.80	0.055	1.022
26	0.619	0.614	645.06	0.025	0.467	76	1.115	1.367	1056.32	0.044	0.835
27	0.750	0.744	775.55	0.030	0.565	77	0.978	0.976	964.76	0.039	0.736
28	0.688	0.741	713.99	0.027	0.518	78	1.960	2.111	1269.16	0.078	1.372
29	0.465	0.483	489.27	0.018	0.351	79	0.984	0.970	968.96	0.039	0.741
30	0.634	0.658	660.50	0.025	0.478	80	1.454	1.502	1187.44	0.058	1.065
31	0.565	0.570	590.48	0.022	0.426	81	1.534	1.398	1208.68	0.061	1.118
32	0.641	0.618	667.69	0.025	0.483	82	1.117	1.085	1058.01	0.044	0.837
33	0.766	0.747	791.33	0.030	0.577	83	1.986	2.212	1272.93	0.079	1.388
34	0.593	0.585	618.90	0.023	0.447	84	1.817	1.754	1251.09	0.072	1.288
35	0.542	0.566	567.94	0.021	0.409	85	1.685	2.352	1238.22	0.067	1.213
36	0.971	0.944	959.87	0.038	0.731	86	1.199	1.491	1103.52	0.047	0.893
37	0.586	0.646	612.51	0.023	0.442	87	1.027	0.918	998.32	0.041	0.772
38	1.013	1.033	988.62	0.040	0.762	88	1.156	1.156	1081.63	0.046	0.864
39	1.257	2.005	1128.89	0.050	0.932	89	2.138	1.820	1290.50	0.085	1.477
40	0.713	0.695	738.86	0.028	0.537	90	1.707	1.879	1240.91	0.068	1.225
41	0.652	0.707	678.39	0.026	0.492	91	1.297	1.176	1143.82	0.051	0.960
42	0.711	0.730	736.69	0.028	0.535	92	1.801	2.019	1249.24	0.071	1.279
43	0.532	0.549	557.92	0.021	0.401	93	1.737	1.472	1244.45	0.069	1.243
44	0.932	1.048	932.27	0.037	0.702	94	2.161	2.835	1293.44	0.086	1.490
45	0.606	0.622	631.82	0.024	0.457	95	1.751	1.501	1245.97	0.069	1.251
46	0.959	1.047	951.54	0.038	0.722	96	2.181	2.027	1295.99	0.086	1.502
47	0.894	0.966	903.53	0.035	0.674	97	2.295	2.448	1310.62	0.091	1.570
48	1.107	1.193	1051.51	0.044	0.830	98	1.968	1.780	1270.37	0.078	1.377
49	1.023	0.985	995.41	0.041	0.769	99	2.026	1.724	1278.00	0.080	1.412
50	0.697	0.730	723.55	0.028	0.526	100	3.852	4.790	1337.73	0.153	2.580

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.6 Results of SDOF Analyses of Frame ‘F2S2B2’

(ATC Idealization Method)

EQ	ATC				
	μ_{ATC}	R_{ATC}	V (kN)	Δ (m)	MIDR (%)
1	0.020	0.020	26.09	0.001	0.016
2	0.037	0.037	44.77	0.001	0.030
3	0.067	0.067	74.77	0.003	0.052
4	0.106	0.106	117.33	0.004	0.081
5	0.105	0.105	117.04	0.004	0.081
6	0.504	0.504	529.44	0.020	0.380
7	0.330	0.330	351.70	0.013	0.249
8	0.257	0.257	276.82	0.010	0.195
9	0.278	0.278	298.49	0.011	0.211
10	0.450	0.450	474.68	0.018	0.340
11	0.246	0.246	265.40	0.010	0.187
12	0.337	0.337	359.05	0.013	0.255
13	0.313	0.313	334.14	0.012	0.237
14	0.407	0.407	430.37	0.016	0.307
15	0.273	0.273	292.65	0.011	0.206
16	0.243	0.243	262.11	0.010	0.184
17	0.457	0.457	481.30	0.018	0.345
18	0.243	0.243	262.04	0.010	0.184
19	0.606	0.606	632.46	0.024	0.457
20	0.322	0.322	344.00	0.013	0.244
21	0.817	0.817	840.14	0.032	0.615
22	0.550	0.550	575.54	0.022	0.415
23	0.665	0.665	691.21	0.026	0.501
24	0.379	0.379	402.31	0.015	0.286
25	0.494	0.494	518.77	0.020	0.372
26	0.615	0.615	640.75	0.024	0.463
27	0.744	0.744	769.60	0.029	0.560
28	0.741	0.741	766.61	0.029	0.558
29	0.483	0.483	508.18	0.019	0.365
30	0.658	0.658	684.08	0.026	0.496
31	0.570	0.570	595.93	0.023	0.430
32	0.618	0.618	643.87	0.024	0.466
33	0.747	0.747	772.93	0.030	0.563
34	0.585	0.585	610.98	0.023	0.441
35	0.566	0.566	591.80	0.022	0.427
36	0.944	0.944	941.19	0.037	0.712
37	0.646	0.646	672.34	0.026	0.487
38	1.035	1.033	1003.38	0.041	0.778
39	1.230	2.005	1117.06	0.049	0.914
40	0.695	0.695	721.16	0.028	0.524
41	0.707	0.707	732.73	0.028	0.532
42	0.730	0.730	755.65	0.029	0.550
43	0.549	0.549	574.42	0.022	0.414
44	1.049	1.048	1013.22	0.042	0.788
45	0.622	0.622	648.17	0.025	0.469
46	1.026	1.047	997.32	0.041	0.771
47	0.966	0.966	956.50	0.038	0.728
48	1.096	1.193	1044.32	0.043	0.822
49	0.986	0.986	969.78	0.039	0.742
50	0.730	0.730	756.13	0.029	0.550
51	0.677	0.677	702.92	0.027	0.510
52	0.809	0.809	833.41	0.032	0.609
53	0.842	0.842	861.92	0.033	0.634
54	1.213	1.333	1109.66	0.048	0.902
55	1.114	1.250	1056.30	0.044	0.835
56	0.755	0.755	781.00	0.030	0.569
57	0.526	0.526	552.01	0.021	0.397
58	0.745	0.745	770.94	0.030	0.561
59	0.831	0.831	852.16	0.033	0.626
60	0.704	0.704	730.15	0.028	0.530
61	0.722	0.722	748.18	0.029	0.544
62	1.269	1.479	1133.77	0.050	0.940
63	0.950	0.950	945.05	0.038	0.716
64	0.847	0.847	866.88	0.034	0.639
65	1.570	1.813	1218.01	0.062	1.142
66	1.114	1.115	1055.71	0.044	0.834
67	1.161	1.149	1084.24	0.046	0.867
68	1.382	2.025	1167.76	0.055	1.017
69	1.236	1.395	1119.74	0.049	0.918
70	1.448	1.451	1185.76	0.057	1.061
71	0.923	0.923	926.13	0.037	0.696
72	0.646	0.646	672.15	0.026	0.487
73	1.432	1.460	1181.50	0.057	1.050
74	1.437	1.932	1182.86	0.057	1.054
75	1.400	1.368	1172.78	0.055	1.029
76	1.157	1.366	1082.35	0.046	0.865
77	0.976	0.976	963.41	0.039	0.735
78	1.822	2.111	1251.76	0.072	1.291
79	0.970	0.970	958.86	0.038	0.730
80	1.201	1.502	1104.48	0.048	0.894
81	1.380	1.398	1167.29	0.055	1.016
82	1.090	1.085	1040.43	0.043	0.818
83	1.674	2.212	1236.65	0.066	1.206
84	1.781	1.754	1248.37	0.071	1.268
85	1.747	2.353	1245.55	0.069	1.249
86	1.378	1.491	1166.57	0.055	1.014
87	0.918	0.918	922.35	0.036	0.692
88	1.109	1.156	1052.45	0.044	0.831
89	2.000	1.820	1274.85	0.079	1.396
90	1.693	1.879	1239.24	0.067	1.217
91	1.206	1.176	1106.83	0.048	0.898
92	1.912	2.019	1262.17	0.076	1.343
93	1.664	1.472	1235.14	0.066	1.200
94	2.133	2.835	1289.97	0.084	1.474
95	1.621	1.501	1228.16	0.064	1.174
96	2.257	2.027	1305.47	0.089	1.547
97	2.313	2.447	1313.14	0.092	1.581
98	2.060	1.780	1281.77	0.082	1.431
99	2.187	1.724	1296.75	0.087	1.506
100	3.520	4.789	1350.44	0.139	2.354

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.7 Results of SDOF Analyses of Frame 'F2S2B2'

(FEMA Idealization Method)

EQ	FEMA					EQ	FEMA				
	μ_{FEMA}	R_{FEMA}	V (kN)	Δ (m)	MIDR (%)		μ_{FEMA}	R_{FEMA}	V (kN)	Δ (m)	MIDR (%)
1	0.019	0.019	27.17	0.001	0.017	51	0.682	0.682	767.00	0.029	0.558
2	0.037	0.037	47.04	0.002	0.031	52	0.734	0.734	822.48	0.032	0.600
3	0.058	0.058	71.00	0.003	0.049	53	0.906	0.906	968.66	0.039	0.741
4	0.097	0.097	116.72	0.004	0.080	54	1.244	1.303	1159.16	0.053	0.996
5	0.097	0.097	117.28	0.004	0.081	55	1.042	1.065	1067.56	0.045	0.848
6	0.462	0.462	526.47	0.020	0.378	56	0.688	0.688	772.63	0.030	0.563
7	0.315	0.315	363.65	0.014	0.258	57	0.561	0.561	635.57	0.024	0.459
8	0.268	0.268	311.45	0.012	0.220	58	0.822	0.822	902.38	0.035	0.672
9	0.283	0.283	328.74	0.012	0.233	59	0.797	0.797	882.37	0.034	0.653
10	0.438	0.438	500.39	0.019	0.359	60	0.661	0.661	743.80	0.028	0.541
11	0.222	0.222	260.42	0.010	0.183	61	0.726	0.726	814.27	0.031	0.594
12	0.303	0.303	351.14	0.013	0.249	62	1.259	1.482	1163.82	0.054	1.007
13	0.319	0.319	369.02	0.014	0.262	63	0.869	0.869	940.66	0.037	0.711
14	0.395	0.395	453.39	0.017	0.324	64	0.833	0.833	911.86	0.036	0.682
15	0.254	0.254	295.45	0.011	0.208	65	1.510	1.863	1231.21	0.065	1.185
16	0.235	0.235	275.01	0.010	0.194	66	1.259	1.147	1163.61	0.054	1.007
17	0.460	0.460	524.93	0.020	0.377	67	1.018	1.017	1050.16	0.044	0.828
18	0.202	0.202	236.99	0.009	0.166	68	1.390	1.931	1202.12	0.060	1.101
19	0.529	0.529	600.34	0.023	0.433	69	1.247	1.436	1160.18	0.054	0.998
20	0.292	0.292	338.43	0.013	0.240	70	1.360	1.479	1193.66	0.059	1.080
21	0.815	0.815	897.22	0.035	0.667	71	0.953	0.953	1003.08	0.041	0.777
22	0.532	0.532	604.18	0.023	0.436	72	0.698	0.698	783.29	0.030	0.571
23	0.698	0.698	783.21	0.030	0.571	73	1.335	1.389	1186.18	0.057	1.062
24	0.409	0.409	468.65	0.018	0.335	74	1.409	1.945	1207.60	0.061	1.115
25	0.451	0.451	514.94	0.019	0.370	75	1.335	1.303	1186.13	0.057	1.062
26	0.620	0.620	699.35	0.027	0.507	76	1.172	1.246	1135.05	0.050	0.943
27	0.715	0.715	801.90	0.031	0.585	77	0.910	0.910	971.71	0.039	0.744
28	0.684	0.684	768.97	0.029	0.560	78	1.752	1.802	1261.19	0.075	1.338
29	0.464	0.464	529.18	0.020	0.380	79	0.995	0.995	1034.26	0.043	0.811
30	0.629	0.629	708.91	0.027	0.514	80	1.316	1.466	1180.49	0.057	1.048
31	0.551	0.551	624.56	0.024	0.451	81	1.430	1.409	1213.77	0.062	1.131
32	0.634	0.634	715.11	0.027	0.519	82	1.102	1.097	1102.56	0.047	0.892
33	0.735	0.735	823.43	0.032	0.601	83	1.613	2.088	1246.06	0.069	1.251
34	0.588	0.588	664.91	0.025	0.481	84	1.706	1.658	1255.34	0.073	1.308
35	0.493	0.493	561.13	0.021	0.404	85	1.841	2.291	1274.66	0.079	1.395
36	0.903	0.903	966.09	0.039	0.738	86	1.231	1.216	1155.35	0.053	0.987
37	0.580	0.580	655.67	0.025	0.474	87	0.922	0.922	980.58	0.040	0.753
38	0.971	0.971	1016.64	0.042	0.792	88	1.096	1.180	1099.44	0.047	0.887
39	1.245	1.894	1159.39	0.054	0.997	89	2.033	1.763	1299.39	0.087	1.518
40	0.701	0.701	787.03	0.030	0.574	90	1.640	2.043	1248.31	0.071	1.267
41	0.612	0.612	690.49	0.026	0.501	91	1.128	1.116	1115.16	0.049	0.911
42	0.718	0.718	804.98	0.031	0.587	92	1.741	1.832	1259.83	0.075	1.331
43	0.523	0.523	593.95	0.022	0.428	93	1.638	1.468	1248.23	0.070	1.267
44	0.925	0.925	982.86	0.040	0.756	94	2.084	2.721	1306.16	0.090	1.551
45	0.604	0.604	682.45	0.026	0.495	95	1.593	1.485	1243.58	0.068	1.238
46	1.003	1.003	1039.64	0.043	0.817	96	2.017	1.839	1297.09	0.087	1.508
47	0.902	0.902	965.55	0.039	0.737	97	2.105	2.699	1309.22	0.091	1.565
48	1.112	1.177	1107.31	0.048	0.899	98	1.836	1.635	1273.95	0.079	1.392
49	0.977	0.977	1021.28	0.042	0.797	99	2.027	1.623	1298.57	0.087	1.515
50	0.700	0.700	785.55	0.030	0.572	100	3.322	4.333	1341.31	0.143	2.418

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.8 Results of SDOF Analyses of Frame 'F2S2B2'

(75%Vy Idealization Method)

EQ	75%Vy					EQ	75%Vy				
	$\mu_{75\%Vy}$	$R_{75\%Vy}$	V (kN)	Δ (m)	MIDR (%)		$\mu_{75\%Vy}$	$R_{75\%Vy}$	V (kN)	Δ (m)	MIDR (%)
1	0.019	0.019	27.59	0.001	0.017	51	0.682	0.682	788.53	0.030	0.575
2	0.037	0.037	48.23	0.002	0.032	52	0.706	0.706	815.37	0.031	0.595
3	0.055	0.055	69.15	0.002	0.048	53	0.924	0.924	1002.21	0.041	0.776
4	0.095	0.095	118.01	0.004	0.081	54	1.251	1.292	1172.53	0.055	1.028
5	0.095	0.095	117.43	0.004	0.081	55	0.998	0.998	1057.34	0.044	0.836
6	0.448	0.448	526.22	0.020	0.378	56	0.692	0.692	799.98	0.031	0.583
7	0.309	0.309	367.34	0.014	0.261	57	0.586	0.586	682.04	0.026	0.494
8	0.267	0.267	319.71	0.012	0.226	58	0.851	0.851	946.78	0.038	0.717
9	0.285	0.285	340.49	0.013	0.241	59	0.784	0.784	890.94	0.035	0.661
10	0.434	0.434	510.06	0.019	0.366	60	0.647	0.647	749.52	0.029	0.545
11	0.213	0.213	257.48	0.009	0.181	61	0.720	0.720	829.89	0.032	0.606
12	0.290	0.290	345.55	0.013	0.245	62	1.281	1.478	1181.67	0.057	1.051
13	0.318	0.318	378.39	0.014	0.269	63	0.846	0.846	942.65	0.037	0.713
14	0.403	0.403	475.72	0.018	0.341	64	0.823	0.823	924.38	0.036	0.694
15	0.243	0.243	291.56	0.011	0.206	65	1.500	1.874	1237.28	0.066	1.208
16	0.234	0.234	281.22	0.010	0.198	66	1.342	1.201	1199.97	0.059	1.096
17	0.455	0.455	534.13	0.020	0.384	67	0.973	0.973	1039.37	0.043	0.816
18	0.185	0.185	224.59	0.008	0.157	68	1.381	1.927	1211.53	0.061	1.125
19	0.499	0.499	584.26	0.022	0.421	69	1.243	1.441	1170.13	0.055	1.023
20	0.283	0.283	337.97	0.013	0.239	70	1.311	1.517	1190.75	0.058	1.073
21	0.809	0.809	912.45	0.036	0.682	71	0.955	0.955	1025.67	0.042	0.802
22	0.526	0.526	614.49	0.023	0.444	72	0.702	0.702	810.67	0.031	0.591
23	0.696	0.696	803.93	0.031	0.586	73	1.298	1.363	1186.96	0.058	1.064
24	0.419	0.419	493.32	0.019	0.354	74	1.408	1.949	1219.20	0.062	1.145
25	0.431	0.431	507.09	0.019	0.364	75	1.282	1.260	1181.91	0.057	1.051
26	0.615	0.615	713.77	0.027	0.518	76	1.122	1.183	1128.29	0.050	0.931
27	0.706	0.706	815.37	0.031	0.595	77	0.885	0.885	972.60	0.039	0.745
28	0.652	0.652	755.04	0.029	0.549	78	1.793	1.692	1275.67	0.079	1.400
29	0.460	0.460	539.51	0.020	0.388	79	1.034	1.033	1082.07	0.046	0.865
30	0.616	0.616	715.85	0.027	0.520	80	1.373	1.465	1209.22	0.061	1.119
31	0.552	0.552	643.74	0.024	0.466	81	1.453	1.405	1228.97	0.064	1.177
32	0.663	0.663	768.00	0.029	0.559	82	1.110	1.100	1122.23	0.049	0.922
33	0.730	0.730	839.66	0.032	0.615	83	1.590	2.048	1248.23	0.070	1.267
34	0.590	0.590	686.37	0.026	0.498	84	1.689	1.619	1259.68	0.075	1.330
35	0.471	0.471	552.94	0.021	0.398	85	1.842	2.221	1281.86	0.082	1.432
36	0.888	0.888	975.28	0.039	0.748	86	1.112	1.096	1123.55	0.049	0.924
37	0.543	0.543	634.09	0.024	0.458	87	0.924	0.924	1002.70	0.041	0.777
38	0.948	0.948	1020.38	0.042	0.796	88	1.099	1.171	1116.93	0.049	0.914
39	1.214	1.832	1161.20	0.054	1.001	89	2.052	1.738	1310.70	0.091	1.571
40	0.702	0.702	810.69	0.031	0.591	90	1.602	2.082	1248.96	0.071	1.274
41	0.585	0.585	680.99	0.026	0.493	91	1.099	1.093	1117.03	0.049	0.914
42	0.707	0.707	816.66	0.031	0.596	92	1.655	1.761	1255.24	0.073	1.308
43	0.515	0.515	602.18	0.023	0.434	93	1.621	1.464	1250.70	0.072	1.286
44	0.881	0.881	969.57	0.039	0.742	94	2.028	2.639	1306.90	0.090	1.554
45	0.605	0.605	703.27	0.027	0.510	95	1.603	1.485	1249.02	0.071	1.275
46	0.982	0.982	1046.00	0.044	0.824	96	1.864	1.761	1284.48	0.083	1.446
47	0.863	0.863	955.88	0.038	0.727	97	2.066	2.847	1312.85	0.092	1.580
48	1.132	1.154	1132.75	0.050	0.938	98	1.761	1.587	1270.71	0.078	1.379
49	0.973	0.973	1039.54	0.043	0.817	99	1.934	1.576	1293.85	0.086	1.492
50	0.689	0.689	796.77	0.031	0.581	100	3.282	4.259	1338.95	0.145	2.461

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.9 Results of SDOF Analyses of Frame 'F3S2B'

(MULTI Idealization Method)

EQ	MULTI					EQ	MULTI				
	μ_{MULTI}	R_{MULTI}	V (kN)	Δ (m)	MIDR (%)		μ_{MULTI}	R_{MULTI}	V (kN)	Δ (m)	MIDR (%)
1	0.037	0.037	44.69	0.002	0.029	51	1.432	1.447	1102.83	0.085	1.162
2	0.038	0.038	45.68	0.002	0.030	52	1.696	1.638	1171.90	0.100	1.351
3	0.122	0.122	129.02	0.007	0.097	53	0.854	0.914	813.10	0.051	0.701
4	0.096	0.096	102.19	0.006	0.076	54	1.525	1.530	1129.05	0.090	1.229
5	0.103	0.103	109.55	0.006	0.081	55	0.997	1.261	899.94	0.059	0.820
6	0.311	0.314	313.23	0.018	0.253	56	2.071	2.311	1229.08	0.123	1.601
7	0.359	0.376	358.68	0.021	0.292	57	0.933	0.950	861.51	0.055	0.766
8	0.439	0.473	434.97	0.026	0.358	58	1.747	2.329	1182.26	0.103	1.386
9	0.497	0.579	490.69	0.029	0.407	59	1.191	1.057	1008.18	0.070	0.978
10	0.474	0.485	468.64	0.028	0.387	60	0.711	0.708	691.55	0.042	0.583
11	0.366	0.373	365.19	0.022	0.298	61	0.881	0.919	829.43	0.052	0.723
12	0.390	0.413	388.47	0.023	0.318	62	1.380	1.877	1087.12	0.082	1.125
13	0.445	0.416	441.00	0.026	0.363	63	1.368	1.879	1083.04	0.081	1.116
14	0.950	1.066	871.79	0.056	0.780	64	1.038	1.041	923.40	0.061	0.853
15	0.248	0.255	252.20	0.015	0.201	65	1.446	1.669	1106.79	0.086	1.172
16	0.512	0.543	504.72	0.030	0.419	66	1.824	2.671	1195.93	0.108	1.438
17	0.690	0.687	671.93	0.041	0.565	67	1.565	1.712	1140.13	0.093	1.258
18	0.409	0.418	407.10	0.024	0.334	68	1.508	1.278	1124.39	0.089	1.217
19	0.819	0.813	788.81	0.048	0.671	69	1.699	2.377	1172.36	0.101	1.352
20	0.787	0.788	761.93	0.047	0.645	70	1.652	1.659	1162.03	0.098	1.320
21	0.991	1.313	896.22	0.059	0.814	71	1.299	1.441	1057.72	0.077	1.064
22	0.831	0.841	797.54	0.049	0.681	72	1.060	0.972	936.01	0.063	0.871
23	0.419	0.410	416.24	0.025	0.342	73	1.712	1.575	1175.19	0.101	1.361
24	0.388	0.413	386.85	0.023	0.317	74	2.118	3.137	1235.86	0.125	1.633
25	0.519	0.548	511.55	0.031	0.425	75	2.187	2.441	1247.26	0.129	1.679
26	1.387	1.375	1089.40	0.082	1.130	76	1.262	1.525	1042.46	0.075	1.035
27	0.906	0.880	845.17	0.054	0.744	77	1.122	0.999	971.09	0.066	0.922
28	0.736	0.711	714.36	0.044	0.603	78	2.560	2.544	1302.14	0.152	1.928
29	0.875	0.865	825.90	0.052	0.718	79	2.042	1.908	1225.14	0.121	1.582
30	0.345	0.349	345.13	0.020	0.281	80	4.056	2.779	1311.13	0.240	2.941
31	0.755	0.752	731.86	0.045	0.618	81	2.344	2.586	1270.43	0.139	1.785
32	1.208	1.144	1017.09	0.072	0.993	82	2.728	2.275	1324.83	0.161	2.043
33	0.960	0.975	877.90	0.057	0.789	83	3.746	1.984	1314.61	0.222	2.734
34	0.668	0.696	650.99	0.040	0.547	84	1.717	2.221	1176.22	0.102	1.365
35	0.863	0.943	818.21	0.051	0.708	85	2.735	3.044	1325.37	0.162	2.047
36	1.111	1.303	964.79	0.066	0.913	86	1.345	1.397	1074.99	0.080	1.098
37	0.828	0.789	795.48	0.049	0.679	87	2.434	2.727	1283.33	0.144	1.844
38	0.827	0.901	794.67	0.049	0.678	88	3.091	2.249	1337.61	0.183	2.289
39	0.794	0.841	767.99	0.047	0.651	89	2.793	2.908	1329.63	0.165	2.087
40	1.249	1.225	1036.58	0.074	1.025	90	2.227	2.294	1253.50	0.132	1.706
41	1.245	1.310	1035.09	0.074	1.022	91	2.935	2.645	1336.19	0.174	2.183
42	1.398	2.257	1092.63	0.083	1.137	92	1.948	2.727	1212.43	0.115	1.520
43	1.230	1.105	1027.72	0.073	1.010	93	2.729	2.141	1324.88	0.162	2.043
44	0.920	0.939	853.49	0.054	0.755	94	4.155	3.039	1307.49	0.246	3.009
45	0.793	0.750	767.20	0.047	0.650	95	2.152	1.903	1241.42	0.127	1.655
46	1.000	1.006	901.78	0.059	0.822	96	2.619	2.666	1311.85	0.155	1.968
47	0.697	0.745	678.33	0.041	0.571	97	2.751	3.058	1326.58	0.163	2.058
48	1.274	1.116	1047.35	0.075	1.044	98	3.011	3.235	1338.05	0.178	2.235
49	1.284	1.308	1051.73	0.076	1.052	99	4.092	2.809	1312.83	0.242	2.967
50	1.101	1.011	958.86	0.065	0.905	100	5.192	4.510	1280.53	0.307	3.712

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.10 Results of SDOF Analyses of Frame 'F3S2B'

(ATC Idealization Method)

EQ	ATC					EQ	ATC				
	μ_{ATC}	R_{ATC}	V (kN)	Δ (m)	MIDR (%)		μ_{ATC}	R_{ATC}	V (kN)	Δ (m)	MIDR (%)
1	0.037	0.037	44.69	0.002	0.029	51	1.582	1.447	1144.51	0.094	1.270
2	0.038	0.038	45.68	0.002	0.030	52	1.458	1.638	1110.51	0.086	1.181
3	0.122	0.122	129.02	0.007	0.097	53	0.914	0.914	850.02	0.054	0.750
4	0.096	0.096	102.19	0.006	0.076	54	1.645	1.530	1160.35	0.097	1.315
5	0.103	0.103	109.55	0.006	0.081	55	1.221	1.261	1023.59	0.072	1.003
6	0.314	0.314	315.85	0.019	0.255	56	2.038	2.311	1224.47	0.121	1.579
7	0.376	0.376	375.36	0.022	0.307	57	0.950	0.950	871.92	0.056	0.780
8	0.473	0.473	467.19	0.028	0.386	58	1.853	2.329	1201.05	0.110	1.458
9	0.579	0.579	567.64	0.034	0.474	59	1.060	1.057	935.73	0.063	0.871
10	0.485	0.485	479.10	0.029	0.397	60	0.708	0.708	688.62	0.042	0.580
11	0.373	0.373	372.20	0.022	0.304	61	0.919	0.919	852.92	0.054	0.754
12	0.413	0.413	410.29	0.024	0.337	62	1.551	1.877	1136.25	0.092	1.248
13	0.416	0.416	413.63	0.025	0.340	63	1.457	1.879	1110.14	0.086	1.180
14	1.069	1.066	941.09	0.063	0.879	64	1.042	1.041	925.78	0.062	0.857
15	0.255	0.255	259.48	0.015	0.207	65	1.644	1.668	1160.12	0.097	1.314
16	0.543	0.543	534.09	0.032	0.444	66	1.610	2.671	1151.84	0.095	1.290
17	0.687	0.687	669.21	0.041	0.563	67	1.548	1.712	1135.38	0.092	1.246
18	0.418	0.418	415.16	0.025	0.341	68	1.298	1.278	1057.22	0.077	1.063
19	0.813	0.813	783.52	0.048	0.666	69	1.723	2.377	1177.61	0.102	1.369
20	0.788	0.788	762.23	0.047	0.645	70	1.720	1.659	1177.01	0.102	1.367
21	1.213	1.313	1019.56	0.072	0.997	71	1.265	1.441	1043.42	0.075	1.037
22	0.841	0.841	804.20	0.050	0.689	72	0.972	0.972	885.08	0.058	0.799
23	0.410	0.410	407.98	0.024	0.335	73	1.519	1.575	1127.31	0.090	1.225
24	0.413	0.413	410.50	0.024	0.337	74	1.691	3.137	1170.82	0.100	1.347
25	0.548	0.548	538.58	0.032	0.448	75	2.269	2.441	1259.55	0.134	1.734
26	1.459	1.375	1110.61	0.086	1.182	76	1.652	1.525	1161.98	0.098	1.320
27	0.880	0.880	828.86	0.052	0.722	77	0.999	0.999	900.97	0.059	0.821
28	0.711	0.711	690.86	0.042	0.582	78	2.789	2.544	1329.34	0.165	2.084
29	0.865	0.865	819.38	0.051	0.709	79	1.683	1.908	1168.98	0.100	1.341
30	0.349	0.349	349.20	0.021	0.284	80	3.902	2.779	1312.38	0.231	2.838
31	0.752	0.752	729.49	0.045	0.616	81	2.163	2.586	1243.31	0.128	1.663
32	1.115	1.144	966.75	0.066	0.916	82	2.931	2.276	1336.08	0.174	2.181
33	0.975	0.975	886.73	0.058	0.801	83	3.391	1.984	1321.33	0.201	2.491
34	0.696	0.696	676.97	0.041	0.570	84	1.668	2.221	1165.76	0.099	1.331
35	0.943	0.943	867.86	0.056	0.775	85	2.404	3.044	1279.05	0.142	1.824
36	1.277	1.303	1048.74	0.076	1.047	86	1.456	1.397	1109.85	0.086	1.180
37	0.789	0.789	763.16	0.047	0.646	87	2.189	2.727	1247.52	0.130	1.681
38	0.901	0.901	842.24	0.053	0.740	88	2.906	2.249	1335.12	0.172	2.163
39	0.841	0.841	804.41	0.050	0.690	89	2.478	2.908	1289.54	0.147	1.874
40	1.231	1.225	1028.52	0.073	1.011	90	2.120	2.294	1236.14	0.125	1.634
41	1.232	1.310	1028.98	0.073	1.012	91	2.813	2.645	1330.81	0.167	2.100
42	1.432	2.257	1102.65	0.085	1.162	92	2.129	2.727	1237.62	0.126	1.640
43	1.116	1.105	967.63	0.066	0.917	93	2.942	2.141	1336.46	0.174	2.188
44	0.939	0.939	865.48	0.056	0.771	94	3.954	3.039	1311.82	0.234	2.872
45	0.750	0.750	727.97	0.044	0.615	95	1.956	1.903	1213.30	0.116	1.525
46	1.006	1.006	905.35	0.060	0.827	96	2.758	2.666	1327.11	0.163	2.063
47	0.745	0.745	723.08	0.044	0.610	97	2.604	3.058	1309.44	0.154	1.958
48	1.127	1.116	973.86	0.067	0.927	98	2.938	3.235	1336.31	0.174	2.185
49	1.269	1.308	1045.42	0.075	1.041	99	3.875	2.809	1312.57	0.229	2.820
50	1.011	1.011	907.90	0.060	0.831	100	4.732	4.510	1293.67	0.280	3.399

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.11 Results of SDOF Analyses of Frame ‘F3S2B’

(FEMA Idealization Method)

EQ	FEMA					EQ	FEMA				
	μ_{FEMA}	R_{FEMA}	V (kN)	Δ (m)	MIDR (%)		μ_{FEMA}	R_{FEMA}	V (kN)	Δ (m)	MIDR (%)
1	0.035	0.035	45.83	0.002	0.030	51	1.367	1.316	1124.58	0.089	1.218
2	0.037	0.037	47.92	0.002	0.032	52	1.440	1.576	1146.51	0.094	1.275
3	0.127	0.127	147.11	0.008	0.112	53	0.811	0.811	838.36	0.053	0.735
4	0.087	0.087	102.48	0.006	0.076	54	1.488	1.378	1159.73	0.097	1.313
5	0.098	0.098	115.67	0.006	0.086	55	1.182	1.197	1059.62	0.077	1.068
6	0.237	0.237	264.98	0.015	0.212	56	1.965	2.245	1244.14	0.128	1.667
7	0.339	0.339	373.72	0.022	0.305	57	0.921	0.921	911.46	0.060	0.836
8	0.379	0.379	415.17	0.025	0.341	58	1.893	2.388	1231.60	0.124	1.613
9	0.493	0.493	534.31	0.032	0.445	59	1.028	1.028	978.16	0.067	0.933
10	0.460	0.460	499.88	0.030	0.415	60	0.654	0.654	701.29	0.043	0.591
11	0.317	0.317	349.97	0.021	0.285	61	0.905	0.905	900.71	0.059	0.821
12	0.344	0.344	378.91	0.022	0.310	62	1.606	1.828	1186.91	0.105	1.403
13	0.432	0.432	471.01	0.028	0.389	63	1.329	1.725	1113.02	0.087	1.188
14	0.955	0.955	932.69	0.062	0.867	64	0.967	0.967	939.96	0.063	0.877
15	0.228	0.228	256.00	0.015	0.204	65	1.447	1.410	1148.50	0.095	1.281
16	0.503	0.503	545.47	0.033	0.454	66	1.494	2.355	1161.13	0.098	1.317
17	0.709	0.709	757.53	0.046	0.641	67	1.487	1.679	1159.36	0.097	1.312
18	0.427	0.427	465.88	0.028	0.385	68	1.254	1.380	1088.29	0.082	1.127
19	0.797	0.797	828.62	0.052	0.722	69	1.667	2.248	1198.67	0.109	1.448
20	0.723	0.723	771.40	0.047	0.654	70	1.674	1.497	1199.97	0.109	1.454
21	1.048	1.047	990.53	0.068	0.951	71	1.279	1.278	1096.76	0.084	1.147
22	0.795	0.795	827.15	0.052	0.720	72	0.985	0.985	951.11	0.064	0.893
23	0.393	0.393	430.48	0.026	0.354	73	1.543	1.603	1173.22	0.101	1.355
24	0.352	0.352	387.33	0.023	0.317	74	1.635	2.897	1192.52	0.107	1.425
25	0.523	0.523	565.75	0.034	0.472	75	2.125	2.390	1270.45	0.139	1.785
26	1.345	1.294	1117.85	0.088	1.200	76	1.317	1.326	1109.21	0.086	1.178
27	0.881	0.881	885.34	0.058	0.799	77	0.862	0.862	872.93	0.056	0.782
28	0.679	0.679	727.01	0.044	0.614	78	2.601	2.579	1333.68	0.170	2.140
29	0.830	0.830	851.41	0.054	0.752	79	1.689	1.945	1202.56	0.110	1.465
30	0.309	0.309	342.21	0.020	0.278	80	3.551	2.667	1312.23	0.232	2.849
31	0.708	0.708	756.71	0.046	0.640	81	2.065	2.412	1260.98	0.135	1.741
32	1.147	1.219	1043.81	0.075	1.038	82	2.385	2.317	1314.04	0.156	1.977
33	0.892	0.892	892.25	0.058	0.809	83	3.126	1.950	1318.89	0.204	2.533
34	0.649	0.649	696.52	0.042	0.587	84	1.570	2.066	1179.61	0.103	1.376
35	0.927	0.927	915.23	0.061	0.841	85	2.349	2.750	1307.41	0.153	1.950
36	1.242	1.219	1083.75	0.081	1.117	86	1.391	1.394	1131.78	0.091	1.236
37	0.784	0.784	819.52	0.051	0.709	87	2.090	2.767	1265.01	0.137	1.759
38	0.851	0.851	865.25	0.056	0.771	88	2.819	2.266	1336.86	0.184	2.302
39	0.735	0.735	782.33	0.048	0.665	89	2.487	2.213	1326.08	0.162	2.054
40	1.237	1.207	1081.86	0.081	1.113	90	2.037	2.318	1256.56	0.133	1.720
41	1.253	1.261	1088.12	0.082	1.127	91	2.692	2.610	1337.41	0.176	2.208
42	1.367	1.822	1124.43	0.089	1.217	92	2.114	2.799	1268.81	0.138	1.777
43	1.130	1.117	1035.98	0.074	1.024	93	2.475	2.073	1325.08	0.162	2.045
44	0.899	0.899	896.80	0.059	0.815	94	3.558	2.837	1312.14	0.232	2.854
45	0.764	0.764	806.17	0.050	0.692	95	1.866	1.865	1227.51	0.122	1.594
46	0.936	0.936	920.74	0.061	0.849	96	2.672	2.634	1336.70	0.175	2.193
47	0.679	0.679	726.99	0.044	0.614	97	2.485	3.109	1325.94	0.162	2.052
48	1.211	1.188	1071.82	0.079	1.092	98	2.880	3.221	1330.28	0.188	2.346
49	1.269	1.305	1093.30	0.083	1.139	99	3.650	2.620	1311.56	0.238	2.922
50	1.000	1.000	960.52	0.065	0.907	100	4.387	4.119	1292.05	0.287	3.473

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.12 Results of SDOF Analyses of Frame 'F3S2B'

(75%Vy Idealization Method)

EQ	75%Vy				
	$\mu_{75\%Vy}$	$R_{75\%Vy}$	V (kN)	Δ (m)	MIDR (%)
1	0.031	0.031	44.33	0.002	0.029
2	0.035	0.035	49.13	0.002	0.033
3	0.129	0.129	159.43	0.009	0.122
4	0.081	0.081	101.98	0.006	0.076
5	0.094	0.094	118.52	0.007	0.089
6	0.193	0.193	232.36	0.013	0.184
7	0.322	0.322	378.43	0.022	0.309
8	0.327	0.327	383.92	0.023	0.314
9	0.464	0.464	537.17	0.032	0.447
10	0.422	0.422	490.75	0.029	0.407
11	0.266	0.266	314.64	0.019	0.254
12	0.349	0.349	408.86	0.024	0.336
13	0.448	0.448	519.27	0.031	0.431
14	0.836	0.836	892.80	0.058	0.810
15	0.215	0.215	257.42	0.015	0.205
16	0.475	0.475	549.74	0.033	0.458
17	0.738	0.738	822.75	0.051	0.714
18	0.434	0.434	503.67	0.030	0.418
19	0.797	0.797	865.01	0.056	0.771
20	0.701	0.701	794.17	0.049	0.677
21	0.980	0.980	989.04	0.068	0.949
22	0.813	0.813	876.74	0.057	0.787
23	0.398	0.398	463.43	0.028	0.383
24	0.317	0.317	372.16	0.022	0.304
25	0.514	0.514	592.58	0.036	0.496
26	1.257	1.227	1116.74	0.088	1.197
27	0.921	0.921	949.83	0.064	0.892
28	0.658	0.658	751.24	0.046	0.635
29	0.799	0.799	866.66	0.056	0.773
30	0.284	0.284	336.03	0.020	0.273
31	0.687	0.687	781.11	0.048	0.664
32	1.088	1.202	1050.40	0.076	1.050
33	0.835	0.835	892.22	0.058	0.809
34	0.648	0.648	740.13	0.045	0.626
35	0.828	0.828	887.01	0.058	0.801
36	1.171	1.158	1086.68	0.082	1.124
37	0.768	0.768	844.56	0.054	0.743
38	0.787	0.787	857.85	0.055	0.761
39	0.755	0.755	834.95	0.053	0.730
40	1.205	1.180	1098.99	0.084	1.153
41	1.317	1.233	1136.20	0.092	1.248
42	1.290	1.793	1127.52	0.090	1.225
43	1.129	1.118	1069.72	0.079	1.088
44	0.909	0.909	941.94	0.063	0.880
45	0.779	0.779	852.39	0.054	0.754
46	0.908	0.908	941.66	0.063	0.880
47	0.709	0.709	800.24	0.049	0.685
48	1.241	1.213	1111.71	0.087	1.184
49	1.242	1.287	1111.90	0.087	1.185
50	0.988	0.988	994.21	0.069	0.956
51	1.228	1.240	1107.01	0.086	1.173
52	1.387	1.592	1157.73	0.097	1.307
53	0.741	0.741	824.52	0.052	0.716
54	1.347	1.284	1145.79	0.094	1.273
55	1.077	1.125	1045.31	0.075	1.041
56	1.927	2.153	1259.65	0.134	1.734
57	0.883	0.883	924.55	0.062	0.855
58	1.768	2.351	1230.81	0.123	1.609
59	1.016	1.016	1011.45	0.071	0.984
60	0.634	0.634	724.47	0.044	0.612
61	0.843	0.843	897.31	0.059	0.816
62	1.588	1.687	1203.67	0.111	1.470
63	1.215	1.572	1102.50	0.085	1.162
64	0.986	0.986	993.35	0.069	0.955
65	1.318	1.286	1136.63	0.092	1.249
66	1.491	2.131	1183.98	0.104	1.392
67	1.439	1.659	1171.64	0.100	1.350
68	1.257	1.439	1116.66	0.088	1.197
69	1.602	2.085	1205.81	0.112	1.480
70	1.573	1.445	1201.01	0.110	1.458
71	1.208	1.189	1100.04	0.084	1.156
72	0.986	0.986	993.11	0.069	0.955
73	1.568	1.606	1200.04	0.109	1.454
74	1.633	2.675	1209.88	0.114	1.504
75	2.035	2.338	1278.08	0.142	1.820
76	1.140	1.201	1074.28	0.079	1.097
77	0.867	0.867	913.95	0.060	0.840
78	2.461	2.529	1334.84	0.172	2.159
79	1.691	1.961	1217.90	0.118	1.549
80	3.376	2.621	1311.82	0.235	2.888
81	2.015	2.267	1274.58	0.140	1.804
82	2.180	2.242	1303.56	0.152	1.934
83	2.980	1.920	1318.57	0.208	2.575
84	1.514	1.961	1188.76	0.106	1.410
85	2.281	2.537	1321.00	0.159	2.015
86	1.322	1.310	1137.82	0.092	1.252
87	2.058	2.779	1281.91	0.144	1.838
88	2.757	2.280	1327.85	0.192	2.393
89	2.488	2.180	1336.04	0.173	2.180
90	1.979	2.306	1268.41	0.138	1.775
91	2.599	2.582	1338.06	0.181	2.269
92	2.064	2.799	1282.99	0.144	1.843
93	2.195	2.031	1306.35	0.153	1.946
94	3.312	2.793	1312.39	0.231	2.837
95	1.830	1.835	1242.11	0.128	1.658
96	2.602	2.503	1338.04	0.181	2.271
97	2.536	3.210	1337.84	0.177	2.219
98	2.844	3.094	1323.36	0.198	2.463
99	3.542	2.511	1306.49	0.247	3.022
100	4.190	3.960	1289.48	0.292	3.538

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.13 Results of SDOF Analyses of Frame ‘F5S2B’

(MULTI Idealization Method)

EQ	MULTI				
	μ_{MULTI}	R_{MULTI}	V (kN)	Δ (m)	MIDR (%)
1	0.026	0.026	18.95	0.002	0.016
2	0.045	0.045	32.74	0.003	0.027
3	0.218	0.216	150.76	0.015	0.130
4	0.087	0.087	64.26	0.006	0.052
5	0.182	0.182	128.48	0.013	0.107
6	0.164	0.164	117.68	0.012	0.097
7	0.407	0.441	256.00	0.029	0.251
8	0.520	0.548	314.58	0.036	0.323
9	0.648	0.782	380.02	0.045	0.405
10	0.456	0.629	281.63	0.032	0.283
11	0.322	0.359	209.77	0.023	0.196
12	0.583	0.585	346.93	0.041	0.364
13	1.029	0.971	568.22	0.072	0.647
14	1.346	1.055	695.45	0.095	0.859
15	0.182	0.189	128.95	0.013	0.108
16	0.572	0.555	341.67	0.040	0.357
17	0.653	0.584	382.76	0.046	0.409
18	0.430	0.620	268.17	0.030	0.266
19	1.318	1.115	687.36	0.093	0.838
20	1.945	1.110	747.83	0.137	1.326
21	0.943	1.071	526.71	0.066	0.593
22	1.209	1.216	650.30	0.085	0.760
23	0.562	0.650	336.56	0.039	0.351
24	0.269	0.338	180.08	0.019	0.162
25	0.711	0.683	411.72	0.050	0.446
26	1.475	1.809	720.03	0.104	0.960
27	1.057	1.132	581.77	0.074	0.665
28	1.403	0.907	708.17	0.098	0.903
29	1.456	1.235	717.25	0.102	0.945
30	0.236	0.266	161.34	0.017	0.141
31	1.277	1.802	674.62	0.090	0.808
32	1.140	1.253	620.58	0.080	0.716
33	0.611	0.660	361.29	0.043	0.382
34	0.683	0.607	397.60	0.048	0.428
35	1.047	0.894	577.02	0.074	0.658
36	0.866	1.109	488.53	0.061	0.543
37	2.150	2.087	757.93	0.151	1.481
38	1.348	1.595	695.83	0.095	0.860
39	0.394	0.453	248.72	0.028	0.242
40	1.413	1.220	709.95	0.099	0.911
41	1.920	1.954	746.73	0.135	1.308
42	0.923	1.156	516.92	0.065	0.580
43	2.100	2.110	755.54	0.147	1.443
44	1.574	1.228	730.46	0.110	1.040
45	1.533	1.903	726.78	0.108	1.007
46	0.564	0.589	337.19	0.040	0.352
47	0.997	0.685	553.18	0.070	0.627
48	1.222	0.961	655.14	0.086	0.769
49	1.512	1.301	724.51	0.106	0.990
50	2.395	2.289	767.19	0.168	1.666

EQ	MULTI				
	μ_{MULTI}	R_{MULTI}	V (kN)	Δ (m)	MIDR (%)
51	2.084	1.693	754.76	0.146	1.430
52	2.371	2.190	766.42	0.166	1.649
53	0.743	0.712	427.60	0.052	0.466
54	NC	NC	NC	NC	NC
55	1.255	1.197	667.35	0.088	0.791
56	3.148	2.878	787.25	0.221	2.228
57	0.784	0.980	447.99	0.055	0.492
58	2.783	2.715	777.60	0.195	1.954
59	5.406	2.318	777.44	0.379	3.982
60	1.244	1.121	663.53	0.087	0.784
61	1.228	1.010	657.45	0.086	0.773
62	2.250	2.656	762.02	0.158	1.557
63	3.077	2.329	785.55	0.216	2.174
64	2.237	1.667	761.53	0.157	1.548
65	0.999	0.746	554.06	0.070	0.628
66	2.325	2.041	764.81	0.163	1.614
67	3.093	2.772	785.94	0.217	2.187
68	1.659	1.945	737.18	0.116	1.109
69	3.176	2.801	787.89	0.223	2.250
70	3.460	2.523	793.14	0.243	2.467
71	1.378	1.879	702.91	0.097	0.883
72	1.456	1.253	717.26	0.102	0.945
73	2.828	3.562	778.92	0.199	1.988
74	2.173	2.105	759.01	0.153	1.499
75	3.675	2.352	796.86	0.258	2.630
76	1.605	1.391	733.16	0.113	1.066
77	6.309	2.945	777.74	0.443	4.747
78	3.157	2.167	787.46	0.222	2.235
79	2.099	3.682	755.51	0.147	1.442
80	3.522	4.578	794.29	0.247	2.513
81	NC	NC	NC	NC	NC
82	4.484	4.159	793.59	0.315	3.249
83	3.476	5.791	793.43	0.244	2.478
84	1.723	2.020	740.84	0.121	1.158
85	4.293	2.528	793.25	0.301	3.097
86	2.639	2.031	772.73	0.185	1.847
87	3.078	4.339	785.59	0.216	2.176
88	3.032	3.511	784.48	0.213	2.141
89	3.102	2.702	786.15	0.218	2.193
90	2.338	3.073	765.29	0.164	1.624
91	5.277	4.470	772.81	0.370	3.886
92	2.238	2.588	761.54	0.157	1.548
93	4.986	3.814	783.00	0.350	3.648
94	3.168	5.220	787.73	0.222	2.244
95	3.759	4.190	797.99	0.264	2.694
96	2.827	4.021	778.89	0.198	1.987
97	1.830	4.421	742.50	0.128	1.240
98	2.669	4.715	773.89	0.187	1.869
99	3.032	4.737	784.48	0.213	2.141
100	3.116	5.082	786.50	0.219	2.204

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.14 Results of SDOF Analyses of Frame 'F5S2B'

(ATC Idealization Method)

EQ	ATC					EQ	ATC				
	μ_{ATC}	R_{ATC}	V (kN)	Δ (m)	MIDR (%)		μ_{ATC}	R_{ATC}	V (kN)	Δ (m)	MIDR (%)
1	0.026	0.026	18.94	0.002	0.016	51	1.865	1.693	744.07	0.131	1.266
2	0.045	0.045	32.72	0.003	0.027	52	2.296	2.191	763.74	0.161	1.592
3	0.216	0.216	149.25	0.015	0.128	53	0.712	0.712	412.24	0.050	0.446
4	0.087	0.087	64.28	0.006	0.052	54	NC	NC	NC	NC	NC
5	0.183	0.183	129.08	0.013	0.108	55	1.148	1.197	624.17	0.081	0.721
6	0.164	0.164	117.71	0.012	0.097	56	2.755	2.878	776.74	0.193	1.933
7	0.442	0.442	274.02	0.031	0.273	57	0.980	0.980	544.88	0.069	0.616
8	0.548	0.548	329.32	0.038	0.342	58	1.960	2.717	748.49	0.138	1.337
9	0.782	0.782	447.22	0.055	0.491	59	4.662	2.318	788.79	0.327	3.391
10	0.630	0.630	370.77	0.044	0.394	60	1.173	1.121	635.70	0.082	0.737
11	0.359	0.359	230.15	0.025	0.220	61	1.011	1.011	559.63	0.071	0.635
12	0.585	0.585	348.35	0.041	0.366	62	2.948	2.657	782.30	0.207	2.078
13	0.971	0.971	540.23	0.068	0.610	63	3.422	2.328	792.41	0.240	2.438
14	1.058	1.055	581.79	0.074	0.665	64	2.032	1.667	752.10	0.143	1.391
15	0.189	0.189	133.26	0.013	0.112	65	0.746	0.746	429.09	0.052	0.468
16	0.555	0.555	332.57	0.039	0.346	66	2.580	2.043	770.45	0.181	1.803
17	0.584	0.584	347.69	0.041	0.365	67	3.183	2.773	788.05	0.223	2.255
18	0.621	0.621	366.45	0.044	0.388	68	1.759	1.946	741.72	0.124	1.186
19	1.119	1.114	610.95	0.079	0.703	69	3.572	2.803	795.17	0.251	2.552
20	1.114	1.110	608.46	0.078	0.700	70	2.722	2.523	775.73	0.191	1.909
21	1.051	1.071	578.84	0.074	0.661	71	1.964	1.880	748.68	0.138	1.340
22	1.246	1.216	664.32	0.088	0.786	72	1.287	1.253	677.69	0.090	0.815
23	0.650	0.650	380.97	0.046	0.407	73	2.329	3.562	764.96	0.164	1.617
24	0.339	0.339	218.99	0.024	0.207	74	2.629	2.105	772.38	0.185	1.840
25	0.683	0.683	397.79	0.048	0.428	75	4.593	2.353	789.50	0.322	3.336
26	1.395	1.809	706.73	0.098	0.897	76	1.315	1.391	686.36	0.092	0.836
27	1.142	1.132	621.42	0.080	0.717	77	6.756	2.945	786.89	0.474	5.123
28	0.907	0.907	508.99	0.064	0.570	78	3.529	2.166	794.42	0.248	2.519
29	1.340	1.236	693.84	0.094	0.855	79	2.258	3.683	762.34	0.159	1.563
30	0.266	0.266	178.37	0.019	0.160	80	3.391	4.581	791.81	0.238	2.414
31	1.668	1.802	737.76	0.117	1.116	81	NC	NC	NC	NC	NC
32	1.300	1.253	681.87	0.091	0.825	82	3.502	4.163	793.92	0.246	2.498
33	0.660	0.660	386.22	0.046	0.413	83	3.888	5.792	795.29	0.273	2.792
34	0.607	0.607	359.45	0.043	0.380	84	1.675	2.022	738.20	0.118	1.121
35	0.894	0.894	502.47	0.063	0.561	85	4.153	2.530	800.15	0.292	2.990
36	1.116	1.109	609.59	0.078	0.701	86	2.202	2.030	760.34	0.155	1.521
37	2.286	2.088	763.37	0.160	1.584	87	2.769	4.340	777.19	0.194	1.944
38	1.362	1.595	699.08	0.096	0.871	88	2.885	3.512	780.56	0.203	2.031
39	0.453	0.453	280.00	0.032	0.280	89	3.082	2.701	785.67	0.216	2.178
40	1.123	1.220	612.85	0.079	0.706	90	2.628	3.075	772.35	0.185	1.839
41	1.724	1.953	740.87	0.121	1.159	91	5.477	4.470	777.91	0.384	4.035
42	1.167	1.157	633.12	0.082	0.733	92	2.011	2.588	750.99	0.141	1.375
43	1.745	2.111	741.79	0.123	1.175	93	5.252	3.813	779.52	0.369	3.861
44	1.464	1.227	718.52	0.103	0.951	94	4.153	5.219	800.15	0.292	2.990
45	1.666	1.903	737.65	0.117	1.114	95	3.402	4.192	792.03	0.239	2.423
46	0.589	0.589	350.16	0.041	0.368	96	2.495	4.021	770.21	0.175	1.741
47	0.685	0.685	398.88	0.048	0.429	97	2.442	4.426	768.65	0.171	1.701
48	0.961	0.961	535.44	0.067	0.604	98	2.821	4.719	778.72	0.198	1.983
49	1.293	1.301	679.52	0.091	0.819	99	2.853	4.737	779.66	0.200	2.007
50	2.337	2.288	765.24	0.164	1.623	100	2.676	5.084	774.18	0.188	1.875

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.15 Results of SDOF Analyses of Frame 'F5S2B'

(FEMA Idealization Method)

EQ	FEMA					EQ	FEMA				
	μ_{FEMA}	R_{FEMA}	V (kN)	Δ (m)	MIDR (%)		μ_{FEMA}	R_{FEMA}	V (kN)	Δ (m)	MIDR (%)
1	0.031	0.031	30.36	0.003	0.025	51	1.740	1.741	766.40	0.166	1.648
2	0.051	0.051	51.48	0.005	0.042	52	1.761	1.954	767.36	0.168	1.670
3	0.190	0.190	174.67	0.018	0.156	53	0.633	0.633	487.00	0.061	0.541
4	0.060	0.060	60.29	0.006	0.049	54	NC	NC	NC	NC	NC
5	0.154	0.154	145.65	0.015	0.125	55	1.066	1.064	716.77	0.102	0.943
6	0.111	0.111	109.23	0.011	0.090	56	2.094	2.535	779.68	0.200	2.008
7	0.405	0.405	331.13	0.039	0.344	57	0.822	0.822	611.52	0.079	0.704
8	0.718	0.718	543.74	0.069	0.615	58	2.283	2.426	786.39	0.218	2.201
9	0.448	0.448	360.90	0.043	0.381	59	4.187	2.329	778.69	0.401	4.208
10	0.350	0.350	292.51	0.033	0.296	60	1.162	1.151	731.28	0.111	1.048
11	0.238	0.238	211.35	0.023	0.198	61	1.164	1.150	731.50	0.111	1.050
12	0.583	0.583	452.99	0.056	0.498	62	1.831	2.042	770.20	0.175	1.740
13	0.969	0.969	688.10	0.093	0.840	63	3.122	2.116	794.10	0.299	3.067
14	1.142	1.126	728.91	0.109	1.026	64	1.606	1.424	759.70	0.154	1.510
15	0.193	0.193	176.59	0.018	0.158	65	0.850	0.850	629.22	0.081	0.728
16	0.432	0.432	350.16	0.041	0.368	66	1.881	1.723	770.11	0.180	1.791
17	0.756	0.756	568.70	0.072	0.647	67	2.515	2.031	792.51	0.241	2.442
18	0.334	0.334	281.33	0.032	0.282	68	1.440	1.500	748.62	0.138	1.339
19	1.183	1.267	733.71	0.113	1.071	69	2.763	2.153	798.07	0.264	2.699
20	1.327	1.253	741.53	0.127	1.223	70	2.538	2.337	793.10	0.243	2.465
21	0.763	0.763	573.46	0.073	0.654	71	1.086	1.083	720.74	0.104	0.964
22	0.971	0.971	688.66	0.093	0.841	72	1.160	1.300	731.02	0.111	1.045
23	0.518	0.518	409.20	0.050	0.442	73	2.225	2.943	784.47	0.213	2.141
24	0.337	0.337	282.94	0.032	0.284	74	2.197	2.084	783.50	0.210	2.113
25	0.717	0.717	543.23	0.069	0.614	75	3.063	3.229	800.29	0.293	3.006
26	1.341	1.346	742.38	0.128	1.237	76	1.277	1.570	741.59	0.122	1.171
27	0.808	0.808	602.57	0.077	0.692	77	3.520	3.284	787.12	0.337	3.499
28	0.998	0.998	698.63	0.095	0.869	78	2.679	2.251	796.46	0.256	2.611
29	1.074	1.134	718.46	0.103	0.951	79	1.709	2.556	764.97	0.164	1.617
30	0.138	0.138	132.18	0.013	0.111	80	2.325	3.064	787.73	0.222	2.244
31	0.982	0.982	693.04	0.094	0.852	81	NC	NC	NC	NC	NC
32	0.801	0.801	598.18	0.077	0.686	82	3.512	3.872	787.10	0.336	3.491
33	0.441	0.441	356.24	0.042	0.376	83	2.819	4.650	798.84	0.270	2.756
34	0.603	0.603	466.73	0.058	0.516	84	1.293	1.428	739.45	0.124	1.187
35	0.963	0.963	685.46	0.092	0.834	85	3.685	2.580	781.75	0.353	3.675
36	0.676	0.676	515.70	0.065	0.578	86	2.146	2.175	781.65	0.205	2.060
37	1.824	1.580	769.95	0.174	1.734	87	2.247	3.162	785.20	0.215	2.163
38	1.113	1.211	724.98	0.106	0.993	88	2.307	3.007	787.16	0.221	2.225
39	0.295	0.295	253.01	0.028	0.248	89	2.133	2.525	781.17	0.204	2.047
40	1.120	1.109	726.03	0.107	1.001	90	1.806	2.308	769.21	0.173	1.715
41	1.791	1.934	768.61	0.171	1.700	91	4.032	3.673	777.98	0.386	4.047
42	0.755	0.755	567.95	0.072	0.646	92	1.643	2.310	761.59	0.157	1.549
43	1.695	1.505	764.24	0.162	1.603	93	3.581	3.693	785.52	0.343	3.563
44	1.349	1.330	742.86	0.129	1.246	94	2.330	4.974	787.88	0.223	2.249
45	1.362	1.283	743.62	0.130	1.259	95	3.678	4.242	782.22	0.352	3.668
46	0.405	0.405	331.54	0.039	0.345	96	2.606	3.207	794.82	0.249	2.536
47	0.917	0.917	665.59	0.088	0.788	97	1.724	2.159	765.69	0.165	1.633
48	0.985	0.985	694.45	0.094	0.856	98	2.016	2.550	776.52	0.193	1.928
49	1.224	1.205	737.75	0.117	1.115	99	2.250	3.947	785.31	0.215	2.167
50	1.668	1.996	762.89	0.160	1.575	100	2.538	3.571	793.11	0.243	2.466

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.16 Results of SDOF Analyses of Frame 'F5S2B'

(75%Vy Idealization Method)

EQ	75%Vy					EQ	75%Vy				
	$\mu_{75\%Vy}$	$R_{75\%Vy}$	V (kN)	Δ (m)	MIDR (%)		$\mu_{75\%Vy}$	$R_{75\%Vy}$	V (kN)	Δ (m)	MIDR (%)
1	0.033	0.033	34.18	0.003	0.028	51	1.698	1.737	766.95	0.168	1.661
2	0.054	0.054	56.08	0.005	0.046	52	1.744	1.883	768.94	0.172	1.709
3	0.190	0.190	178.87	0.019	0.161	53	0.647	0.647	510.13	0.064	0.571
4	0.058	0.058	60.41	0.006	0.049	54	NC	NC	NC	NC	NC
5	0.146	0.146	142.81	0.014	0.122	55	0.977	0.977	701.84	0.096	0.880
6	0.114	0.114	114.96	0.011	0.095	56	2.060	2.531	780.85	0.203	2.039
7	0.387	0.387	326.96	0.038	0.339	57	0.885	0.885	663.25	0.087	0.784
8	0.722	0.722	561.76	0.071	0.638	58	1.950	2.657	776.29	0.192	1.923
9	0.412	0.412	345.32	0.041	0.362	59	4.144	2.344	779.12	0.409	4.302
10	0.368	0.368	313.25	0.036	0.322	60	1.130	1.122	731.77	0.112	1.052
11	0.234	0.234	213.79	0.023	0.201	61	1.122	1.114	730.70	0.111	1.042
12	0.564	0.564	452.34	0.056	0.497	62	1.718	1.968	767.84	0.170	1.681
13	1.005	1.005	709.89	0.099	0.911	63	3.025	2.030	794.46	0.298	3.065
14	1.195	1.167	738.52	0.118	1.125	64	1.539	1.389	758.55	0.152	1.491
15	0.179	0.179	169.84	0.018	0.151	65	0.858	0.858	649.41	0.085	0.758
16	0.422	0.422	352.60	0.042	0.371	66	1.958	1.812	776.65	0.193	1.931
17	0.800	0.800	613.47	0.079	0.706	67	2.496	2.019	794.03	0.246	2.503
18	0.327	0.327	283.44	0.032	0.285	68	1.393	1.454	748.41	0.137	1.336
19	1.262	1.260	739.95	0.125	1.196	69	2.644	2.212	797.44	0.261	2.662
20	1.361	1.273	746.36	0.134	1.302	70	2.516	2.325	794.54	0.248	2.524
21	0.751	0.751	581.06	0.074	0.664	71	1.032	1.032	716.44	0.102	0.941
22	0.957	0.957	694.99	0.094	0.858	72	1.143	1.308	733.22	0.113	1.066
23	0.476	0.476	390.49	0.047	0.419	73	2.236	2.853	787.13	0.221	2.224
24	0.348	0.348	298.74	0.034	0.304	74	2.066	2.103	781.09	0.204	2.045
25	0.776	0.776	597.45	0.077	0.685	75	2.952	3.254	800.13	0.291	2.987
26	1.330	1.273	744.32	0.131	1.270	76	1.273	1.541	740.73	0.126	1.209
27	0.784	0.784	602.85	0.077	0.692	77	3.731	3.207	779.32	0.368	3.856
28	1.020	1.020	713.64	0.101	0.928	78	2.555	2.245	795.48	0.252	2.566
29	1.131	1.204	731.84	0.112	1.053	79	1.675	2.393	765.86	0.165	1.636
30	0.133	0.133	131.47	0.013	0.110	80	2.259	3.020	787.87	0.223	2.249
31	0.892	0.892	667.11	0.088	0.791	81	NC	NC	NC	NC	NC
32	0.805	0.805	616.74	0.079	0.711	82	3.347	4.124	784.42	0.330	3.430
33	0.420	0.420	350.90	0.041	0.369	83	2.713	4.499	798.57	0.268	2.735
34	0.641	0.641	506.21	0.063	0.566	84	1.252	1.386	740.98	0.124	1.186
35	0.953	0.953	693.71	0.094	0.854	85	3.761	2.788	774.18	0.371	3.893
36	0.639	0.639	504.46	0.063	0.564	86	2.148	2.195	784.15	0.212	2.131
37	1.628	1.532	763.47	0.161	1.587	87	2.229	3.065	786.91	0.220	2.217
38	1.129	1.236	731.55	0.111	1.050	88	2.152	2.957	784.28	0.212	2.135
39	0.280	0.280	248.46	0.028	0.242	89	2.021	2.492	779.30	0.199	1.998
40	1.112	1.103	729.54	0.110	1.032	90	1.692	2.209	766.64	0.167	1.654
41	1.767	1.925	769.90	0.174	1.732	91	3.941	3.602	778.16	0.389	4.081
42	0.715	0.715	557.02	0.071	0.632	92	1.620	2.351	763.06	0.160	1.578
43	1.580	1.450	761.02	0.156	1.535	93	3.386	3.676	787.09	0.334	3.470
44	1.373	1.387	747.19	0.136	1.315	94	2.235	4.910	787.11	0.221	2.224
45	1.342	1.272	745.12	0.132	1.282	95	3.516	3.978	784.09	0.347	3.612
46	0.396	0.396	333.80	0.039	0.347	96	2.794	2.948	797.01	0.276	2.820
47	0.960	0.960	696.02	0.095	0.861	97	1.402	1.998	748.95	0.138	1.345
48	0.990	0.990	706.04	0.098	0.894	98	2.045	2.366	780.25	0.202	2.023
49	1.234	1.214	741.33	0.122	1.167	99	2.208	3.844	786.20	0.218	2.195
50	1.575	1.995	760.77	0.155	1.529	100	2.362	3.518	790.62	0.233	2.360

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.17 Results of SDOF Analyses of Frame 'F5S4B'

(MULTI Idealization Method)

EQ	MULTI					EQ	MULTI				
	μ_{MULTI}	R_{MULTI}	V (kN)	Δ (m)	MIDR (%)		μ_{MULTI}	R_{MULTI}	V (kN)	Δ (m)	MIDR (%)
1	0.038	0.038	110.55	0.005	0.030	51	1.592	1.509	3192.96	0.198	1.420
2	0.051	0.051	151.14	0.006	0.040	52	1.458	1.561	3110.08	0.181	1.292
3	0.173	0.171	495.88	0.022	0.141	53	0.624	0.621	1628.13	0.078	0.524
4	0.064	0.064	192.31	0.008	0.050	54	2.001	1.742	3358.08	0.249	1.802
5	0.096	0.097	287.16	0.012	0.076	55	0.985	0.761	2497.09	0.123	0.832
6	0.097	0.099	289.99	0.012	0.077	56	2.180	2.548	3405.24	0.271	1.965
7	0.225	0.244	630.97	0.028	0.185	57	1.014	0.761	2556.20	0.126	0.858
8	0.488	0.470	1292.58	0.061	0.409	58	1.783	2.063	3281.67	0.222	1.600
9	0.553	0.456	1452.40	0.069	0.464	59	3.491	2.243	3577.14	0.434	3.076
10	0.274	0.287	755.66	0.034	0.227	60	0.916	0.877	2336.67	0.114	0.773
11	0.243	0.244	674.99	0.030	0.200	61	0.963	0.994	2446.43	0.120	0.812
12	0.549	0.547	1442.18	0.068	0.460	62	1.216	1.498	2882.57	0.151	1.053
13	0.912	0.904	2327.16	0.114	0.769	63	1.895	1.680	3325.36	0.236	1.705
14	1.177	1.182	2832.52	0.146	1.014	64	1.268	1.145	2943.14	0.158	1.105
15	0.190	0.189	538.24	0.024	0.155	65	0.811	0.802	2084.29	0.101	0.684
16	0.398	0.378	1067.81	0.049	0.332	66	1.309	1.643	2983.43	0.163	1.145
17	0.678	0.629	1760.61	0.084	0.570	67	2.108	1.852	3385.94	0.262	1.899
18	0.277	0.288	761.59	0.034	0.229	68	1.444	1.061	3099.64	0.180	1.278
19	0.908	1.023	2315.68	0.113	0.765	69	2.103	2.287	3384.82	0.262	1.895
20	1.727	1.270	3256.46	0.215	1.547	70	2.288	2.132	3429.57	0.285	2.063
21	0.642	0.661	1671.64	0.080	0.540	71	0.761	0.789	1962.47	0.095	0.641
22	1.039	0.840	2602.78	0.129	0.881	72	1.335	1.162	3008.14	0.166	1.170
23	0.384	0.360	1032.25	0.048	0.320	73	1.674	2.078	3235.14	0.208	1.497
24	0.322	0.308	876.71	0.040	0.267	74	1.700	1.873	3243.52	0.211	1.522
25	0.617	0.727	1609.55	0.077	0.518	75	2.112	2.802	3387.11	0.263	1.903
26	1.026	0.888	2579.19	0.128	0.869	76	1.072	1.141	2665.28	0.133	0.912
27	0.630	0.643	1642.72	0.078	0.530	77	5.157	3.053	3711.98	0.642	4.375
28	1.406	1.176	3069.52	0.175	1.241	78	1.763	1.961	3272.93	0.219	1.581
29	1.347	1.302	3018.93	0.168	1.182	79	1.504	1.692	3140.70	0.187	1.336
30	0.091	0.092	271.68	0.011	0.072	80	2.711	2.902	3507.54	0.337	2.432
31	1.012	0.830	2551.51	0.126	0.856	81	5.087	3.979	3708.68	0.633	4.320
32	0.768	0.684	1979.96	0.096	0.647	82	2.629	3.785	3494.47	0.327	2.362
33	0.287	0.311	787.22	0.036	0.237	83	1.881	3.425	3321.02	0.234	1.692
34	0.883	0.792	2256.60	0.110	0.744	84	1.225	1.081	2894.38	0.152	1.063
35	0.635	0.742	1656.03	0.079	0.534	85	2.403	2.811	3452.45	0.299	2.166
36	0.673	0.590	1748.67	0.084	0.566	86	1.877	1.992	3319.57	0.233	1.688
37	1.643	1.400	3220.43	0.204	1.468	87	2.081	2.618	3379.83	0.259	1.875
38	1.220	1.186	2888.18	0.152	1.057	88	2.382	2.413	3448.15	0.296	2.147
39	0.205	0.204	579.10	0.026	0.168	89	2.313	2.143	3434.51	0.288	2.085
40	1.205	0.938	2869.23	0.150	1.042	90	1.687	1.901	3238.80	0.210	1.510
41	1.013	1.451	2554.26	0.126	0.857	91	3.116	3.021	3546.97	0.388	2.765
42	0.464	0.537	1232.60	0.058	0.388	92	1.658	1.990	3227.87	0.206	1.482
43	1.163	1.142	2813.39	0.145	1.000	93	2.818	3.106	3523.06	0.351	2.523
44	1.632	1.431	3214.27	0.203	1.457	94	2.880	4.105	3531.57	0.358	2.577
45	1.242	0.975	2914.49	0.155	1.080	95	1.993	2.561	3356.05	0.248	1.795
46	0.298	0.310	815.89	0.037	0.247	96	1.269	1.826	2943.71	0.158	1.106
47	0.878	0.925	2244.13	0.109	0.740	97	1.147	1.361	2791.16	0.143	0.985
48	0.994	0.945	2516.12	0.124	0.840	98	1.739	1.673	3262.04	0.216	1.558
49	1.149	1.132	2793.89	0.143	0.986	99	1.973	2.984	3350.50	0.245	1.777
50	1.493	1.651	3133.88	0.186	1.326	100	2.070	2.378	3377.07	0.257	1.865

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.18 Results of SDOF Analyses of Frame 'F5S4B'

(ATC Idealization Method)

EQ	ATC					EQ	ATC				
	μ_{ATC}	R_{ATC}	V (kN)	Δ (m)	MIDR (%)		μ_{ATC}	R_{ATC}	V (kN)	Δ (m)	MIDR (%)
1	0.038	0.038	110.52	0.005	0.030	51	1.285	1.510	2960.92	0.160	1.122
2	0.051	0.051	151.13	0.006	0.040	52	1.540	1.561	3163.23	0.192	1.370
3	0.171	0.171	490.79	0.021	0.139	53	0.621	0.621	1620.43	0.077	0.522
4	0.064	0.064	192.24	0.008	0.050	54	2.102	1.742	3384.48	0.262	1.894
5	0.097	0.097	290.44	0.012	0.077	55	0.761	0.761	1962.07	0.095	0.641
6	0.099	0.099	295.38	0.012	0.078	56	1.996	2.548	3356.77	0.248	1.798
7	0.244	0.244	679.16	0.030	0.201	57	0.761	0.761	1961.14	0.095	0.640
8	0.470	0.470	1248.46	0.058	0.394	58	1.819	2.064	3296.89	0.226	1.633
9	0.456	0.456	1212.23	0.057	0.381	59	3.448	2.243	3570.93	0.429	3.042
10	0.287	0.287	788.29	0.036	0.238	60	0.877	0.877	2241.76	0.109	0.739
11	0.244	0.244	678.88	0.030	0.201	61	0.994	0.994	2515.89	0.124	0.839
12	0.547	0.547	1437.87	0.068	0.459	62	1.383	1.498	3050.21	0.172	1.218
13	0.904	0.904	2307.12	0.112	0.762	63	1.545	1.680	3165.97	0.192	1.375
14	1.209	1.182	2874.45	0.150	1.046	64	1.164	1.145	2814.54	0.145	1.001
15	0.189	0.189	536.38	0.023	0.154	65	0.802	0.802	2060.40	0.100	0.675
16	0.378	0.378	1017.62	0.047	0.315	66	1.693	1.643	3240.74	0.211	1.516
17	0.630	0.630	1641.86	0.078	0.529	67	2.176	1.852	3404.22	0.271	1.961
18	0.288	0.288	791.37	0.036	0.239	68	1.063	1.060	2648.51	0.132	0.904
19	1.023	1.023	2573.83	0.127	0.866	69	1.679	2.287	3237.03	0.209	1.502
20	1.343	1.270	3015.08	0.167	1.178	70	2.360	2.132	3443.50	0.294	2.128
21	0.661	0.661	1717.97	0.082	0.556	71	0.789	0.789	2029.40	0.098	0.664
22	0.840	0.840	2153.66	0.105	0.708	72	1.188	1.162	2846.73	0.148	1.024
23	0.360	0.360	973.91	0.045	0.300	73	1.814	2.079	3294.70	0.226	1.629
24	0.308	0.308	840.82	0.038	0.255	74	1.596	1.873	3194.89	0.199	1.423
25	0.727	0.727	1879.59	0.090	0.612	75	2.039	2.802	3368.81	0.254	1.837
26	0.888	0.888	2268.93	0.110	0.749	76	1.064	1.141	2649.46	0.132	0.904
27	0.643	0.643	1675.45	0.080	0.541	77	4.570	3.052	3669.04	0.569	3.922
28	1.125	1.176	2756.69	0.140	0.963	78	1.989	1.961	3354.92	0.247	1.792
29	1.220	1.302	2888.37	0.152	1.058	79	1.498	1.692	3137.26	0.186	1.331
30	0.092	0.092	273.33	0.011	0.072	80	2.102	2.902	3384.42	0.261	1.894
31	0.830	0.830	2128.89	0.103	0.699	81	4.032	3.979	3621.01	0.502	3.506
32	0.684	0.684	1774.34	0.085	0.575	82	3.465	3.785	3573.25	0.431	3.055
33	0.311	0.311	848.94	0.039	0.258	83	1.961	3.426	3346.98	0.244	1.766
34	0.791	0.791	2035.28	0.098	0.666	84	1.066	1.081	2653.39	0.133	0.906
35	0.742	0.742	1915.39	0.092	0.624	85	2.661	2.811	3499.93	0.331	2.389
36	0.590	0.590	1543.84	0.073	0.495	86	1.815	1.992	3295.39	0.226	1.630
37	1.469	1.400	3117.89	0.183	1.302	87	1.934	2.619	3338.31	0.241	1.741
38	1.105	1.186	2722.72	0.137	0.944	88	1.913	2.414	3331.06	0.238	1.722
39	0.204	0.204	576.88	0.025	0.167	89	2.159	2.143	3399.75	0.269	1.946
40	0.938	0.938	2388.70	0.117	0.791	90	1.473	1.901	3120.68	0.183	1.306
41	1.422	1.451	3082.10	0.177	1.256	91	3.187	3.021	3554.92	0.396	2.824
42	0.537	0.537	1412.86	0.067	0.450	92	1.736	1.990	3260.70	0.216	1.556
43	1.153	1.142	2799.28	0.143	0.990	93	2.753	3.106	3513.70	0.343	2.468
44	1.400	1.431	3064.58	0.174	1.235	94	2.427	4.105	3457.44	0.302	2.187
45	0.975	0.975	2474.70	0.121	0.823	95	1.693	2.562	3240.40	0.211	1.515
46	0.310	0.310	846.01	0.039	0.257	96	1.752	1.827	3268.09	0.218	1.571
47	0.925	0.925	2357.19	0.115	0.780	97	1.439	1.361	3095.77	0.179	1.273
48	0.945	0.945	2404.61	0.118	0.797	98	1.717	1.673	3251.97	0.214	1.538
49	1.140	1.132	2780.72	0.142	0.978	99	1.852	2.984	3310.16	0.230	1.664
50	1.420	1.652	3080.84	0.177	1.254	100	2.117	2.379	3388.52	0.263	1.908

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.19 Results of SDOF Analyses of Frame 'F5S4B'

(FEMA Idealization Method)

EQ	FEMA					EQ	FEMA				
	μ_{FEMA}	R_{FEMA}	V (kN)	Δ (m)	MIDR (%)		μ_{FEMA}	R_{FEMA}	V (kN)	Δ (m)	MIDR (%)
1	0.035	0.035	127.54	0.005	0.034	51	1.379	1.302	3255.80	0.215	1.546
2	0.036	0.036	133.36	0.006	0.035	52	1.303	1.271	3213.97	0.203	1.456
3	0.147	0.147	524.38	0.023	0.150	53	0.552	0.552	1792.82	0.086	0.582
4	0.069	0.069	257.19	0.011	0.068	54	1.791	1.563	3419.32	0.279	2.020
5	0.077	0.077	288.28	0.012	0.076	55	0.884	0.884	2725.29	0.138	0.945
6	0.071	0.071	265.35	0.011	0.070	56	1.907	2.304	3449.03	0.297	2.151
7	0.208	0.208	721.80	0.032	0.215	57	0.904	0.904	2767.73	0.141	0.969
8	0.426	0.426	1402.92	0.066	0.447	58	1.657	1.863	3378.00	0.258	1.868
9	0.517	0.517	1683.69	0.080	0.544	59	2.968	2.075	3597.17	0.462	3.257
10	0.236	0.236	808.40	0.037	0.244	60	0.784	0.784	2487.33	0.122	0.828
11	0.262	0.262	892.60	0.041	0.273	61	0.900	0.900	2758.50	0.140	0.964
12	0.528	0.528	1719.63	0.082	0.556	62	1.066	1.064	3007.23	0.166	1.169
13	0.831	0.831	2606.62	0.129	0.883	63	1.693	1.740	3389.04	0.264	1.909
14	1.044	1.043	2981.35	0.163	1.143	64	1.060	1.058	3000.03	0.165	1.162
15	0.232	0.232	795.75	0.036	0.240	65	0.700	0.700	2240.70	0.109	0.739
16	0.324	0.324	1088.57	0.051	0.339	66	1.266	1.482	3188.42	0.197	1.412
17	0.641	0.641	2062.62	0.100	0.676	67	1.831	1.661	3430.33	0.285	2.066
18	0.254	0.254	865.64	0.039	0.264	68	1.281	1.247	3199.10	0.199	1.430
19	0.841	0.841	2629.22	0.131	0.894	69	1.930	1.655	3454.99	0.300	2.177
20	1.302	1.246	3213.49	0.203	1.455	70	1.856	1.874	3436.25	0.289	2.095
21	0.570	0.570	1846.17	0.089	0.600	71	0.621	0.621	2000.08	0.097	0.654
22	0.939	0.939	2830.66	0.146	1.013	72	1.137	1.167	3083.05	0.177	1.257
23	0.427	0.427	1407.37	0.066	0.448	73	1.383	1.585	3258.50	0.215	1.551
24	0.337	0.337	1127.29	0.052	0.352	74	1.495	1.418	3317.80	0.233	1.683
25	0.597	0.597	1927.17	0.093	0.629	75	1.896	1.759	3446.23	0.295	2.139
26	0.898	0.898	2754.43	0.140	0.961	76	0.892	0.892	2741.38	0.139	0.954
27	0.578	0.578	1871.38	0.090	0.609	77	4.465	3.652	3733.81	0.695	4.661
28	1.137	1.161	3083.29	0.177	1.257	78	1.803	1.599	3422.69	0.281	2.034
29	1.071	1.068	3012.57	0.167	1.175	79	1.309	1.279	3218.09	0.204	1.464
30	0.070	0.070	260.48	0.011	0.069	80	1.922	2.899	3453.04	0.299	2.168
31	0.942	0.942	2834.37	0.147	1.015	81	3.816	4.686	3686.62	0.594	4.080
32	0.643	0.643	2069.40	0.100	0.678	82	2.345	3.411	3534.86	0.365	2.623
33	0.237	0.237	812.20	0.037	0.246	83	1.480	2.519	3310.42	0.230	1.665
34	0.790	0.790	2504.02	0.123	0.835	84	1.072	1.069	3014.08	0.167	1.177
35	0.481	0.481	1574.86	0.075	0.506	85	1.976	2.140	3466.76	0.308	2.228
36	0.601	0.601	1942.01	0.094	0.634	86	1.515	1.719	3325.63	0.236	1.706
37	1.281	1.242	3199.01	0.199	1.430	87	1.649	2.187	3375.63	0.257	1.860
38	1.097	1.091	3040.86	0.171	1.208	88	2.021	1.997	3477.22	0.315	2.276
39	0.152	0.152	541.37	0.024	0.156	89	2.036	2.109	3480.47	0.317	2.293
40	0.916	0.916	2790.22	0.143	0.984	90	1.313	1.622	3220.67	0.204	1.468
41	0.912	0.912	2783.12	0.142	0.979	91	2.576	2.485	3559.18	0.401	2.853
42	0.364	0.364	1211.96	0.057	0.381	92	1.531	1.702	3332.26	0.238	1.725
43	0.903	0.903	2764.40	0.141	0.967	93	2.220	2.510	3517.39	0.346	2.489
44	1.459	1.285	3299.73	0.227	1.640	94	2.314	3.308	3533.34	0.360	2.591
45	1.086	1.081	3029.93	0.169	1.195	95	1.503	1.619	3321.02	0.234	1.692
46	0.243	0.243	832.02	0.038	0.252	96	1.098	1.209	3042.62	0.171	1.210
47	0.752	0.752	2397.50	0.117	0.794	97	1.054	1.048	2992.89	0.164	1.154
48	0.802	0.802	2536.14	0.125	0.849	98	1.494	1.690	3317.17	0.233	1.681
49	0.967	0.967	2875.38	0.151	1.047	99	1.543	2.245	3337.25	0.240	1.738
50	1.343	1.285	3237.35	0.209	1.503	100	1.819	1.751	3427.22	0.283	2.053

V : Maximum Base Shear

Δ : Maximum Roof Displacement

MIDR : Maximum Inter-Story Drift Ratio

NC : Not Considered

Table A.3.20 Results of SDOF Analyses of Frame 'F5S4B'

(75%Vy Idealization Method)

EQ	75%Vy					EQ	75%Vy				
	$\mu_{75\%Vy}$	$R_{75\%Vy}$	V (kN)	Δ (m)	MIDR (%)		$\mu_{75\%Vy}$	$R_{75\%Vy}$	V (kN)	Δ (m)	MIDR (%)
1	0.033	0.033	125.88	0.005	0.034	51	1.351	1.284	3257.65	0.215	1.550
2	0.034	0.034	128.71	0.005	0.034	52	1.271	1.244	3212.28	0.202	1.453
3	0.145	0.145	527.90	0.023	0.151	53	0.543	0.543	1803.65	0.087	0.585
4	0.068	0.068	261.97	0.011	0.069	54	1.741	1.537	3416.69	0.277	2.010
5	0.075	0.075	286.17	0.012	0.076	55	0.904	0.904	2805.37	0.144	0.995
6	0.071	0.071	269.90	0.011	0.071	56	1.898	2.265	3458.03	0.302	2.190
7	0.212	0.212	747.80	0.034	0.224	57	0.900	0.900	2797.73	0.143	0.989
8	0.417	0.417	1406.83	0.066	0.448	58	1.627	1.885	3380.35	0.259	1.877
9	0.520	0.520	1729.08	0.083	0.559	59	2.922	2.057	3598.76	0.465	3.279
10	0.231	0.231	812.02	0.037	0.246	60	0.773	0.773	2507.60	0.123	0.836
11	0.263	0.263	913.34	0.042	0.280	61	0.905	0.905	2807.80	0.144	0.996
12	0.523	0.523	1741.08	0.083	0.564	62	1.022	1.022	2983.66	0.163	1.145
13	0.819	0.819	2621.20	0.130	0.890	63	1.681	1.713	3398.02	0.268	1.940
14	1.019	1.019	2980.37	0.162	1.142	64	1.052	1.050	3019.11	0.168	1.183
15	0.239	0.239	837.19	0.038	0.254	65	0.688	0.688	2250.63	0.110	0.742
16	0.318	0.318	1091.94	0.051	0.340	66	1.242	1.440	3192.22	0.198	1.418
17	0.632	0.632	2077.99	0.101	0.681	67	1.799	1.640	3432.85	0.287	2.078
18	0.255	0.255	888.40	0.041	0.271	68	1.273	1.240	3213.57	0.203	1.455
19	0.814	0.814	2610.97	0.130	0.885	69	1.951	1.582	3471.66	0.311	2.250
20	1.302	1.245	3232.09	0.207	1.490	70	1.795	1.844	3431.69	0.286	2.072
21	0.576	0.576	1904.91	0.092	0.621	71	0.606	0.606	1998.68	0.097	0.654
22	0.951	0.951	2885.66	0.152	1.055	72	1.175	1.175	3140.94	0.187	1.336
23	0.427	0.427	1437.84	0.068	0.459	73	1.391	1.536	3280.73	0.222	1.598
24	0.341	0.341	1164.54	0.054	0.365	74	1.468	1.400	3320.75	0.234	1.691
25	0.579	0.579	1915.20	0.092	0.624	75	1.720	1.685	3410.27	0.274	1.985
26	0.907	0.907	2810.08	0.144	0.998	76	0.874	0.874	2746.01	0.139	0.957
27	0.591	0.591	1951.91	0.094	0.637	77	4.398	3.702	3735.36	0.701	4.689
28	1.170	1.182	3136.91	0.186	1.330	78	1.785	1.561	3429.12	0.284	2.061
29	1.040	1.039	3005.73	0.166	1.168	79	1.265	1.242	3207.87	0.201	1.445
30	0.070	0.070	266.16	0.011	0.070	80	1.903	2.891	3459.45	0.303	2.196
31	0.935	0.935	2859.25	0.149	1.034	81	3.821	4.706	3696.54	0.609	4.170
32	0.659	0.659	2162.36	0.105	0.711	82	2.206	3.337	3524.08	0.351	2.530
33	0.232	0.232	815.45	0.037	0.247	83	1.445	2.438	3309.70	0.230	1.663
34	0.763	0.763	2478.84	0.122	0.825	84	1.072	1.069	3040.50	0.171	1.207
35	0.455	0.455	1527.06	0.073	0.490	85	1.936	2.093	3468.08	0.308	2.234
36	0.599	0.599	1977.49	0.095	0.646	86	1.484	1.690	3326.48	0.236	1.710
37	1.316	1.269	3238.35	0.210	1.507	87	1.624	2.142	3379.67	0.259	1.874
38	1.082	1.078	3051.83	0.172	1.220	88	2.023	1.962	3487.90	0.322	2.329
39	0.148	0.148	536.79	0.024	0.154	89	2.012	2.109	3485.55	0.321	2.317
40	0.920	0.920	2833.24	0.147	1.015	90	1.330	1.579	3245.31	0.212	1.525
41	0.861	0.861	2718.12	0.137	0.941	91	2.521	2.432	3559.77	0.402	2.857
42	0.345	0.345	1178.32	0.055	0.370	92	1.496	1.655	3331.85	0.238	1.724
43	0.884	0.884	2767.55	0.141	0.969	93	2.164	2.453	3516.29	0.345	2.483
44	1.428	1.260	3301.21	0.228	1.643	94	2.288	3.228	3535.17	0.365	2.619
45	1.079	1.074	3048.39	0.172	1.216	95	1.431	1.575	3302.82	0.228	1.647
46	0.238	0.238	833.33	0.038	0.253	96	1.076	1.148	3044.95	0.171	1.212
47	0.734	0.734	2392.27	0.117	0.792	97	1.009	1.009	2967.14	0.161	1.129
48	0.786	0.786	2540.40	0.125	0.851	98	1.489	1.675	3328.66	0.237	1.716
49	0.945	0.945	2876.38	0.151	1.048	99	1.516	2.180	3340.83	0.242	1.748
50	1.290	1.247	3225.06	0.206	1.476	100	1.858	1.751	3447.60	0.296	2.145

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.21 Results of SDOF Analyses of Frame 'F5S7B'

(MULTI Idealization Method)

EQ	MULTI					EQ	MULTI				
	μ_{MULTI}	R_{MULTI}	V (kN)	Δ (m)	MIDR (%)		μ_{MULTI}	R_{MULTI}	V (kN)	Δ (m)	MIDR (%)
1	0.029	0.029	81.60	0.002	0.018	51	1.591	1.037	2831.89	0.111	1.128
2	0.030	0.030	86.01	0.002	0.019	52	2.365	2.471	3080.12	0.164	1.755
3	0.180	0.173	450.30	0.013	0.116	53	0.648	0.633	1430.74	0.045	0.420
4	0.091	0.091	246.78	0.006	0.058	54	1.479	1.258	2743.04	0.103	1.036
5	0.158	0.171	400.66	0.011	0.102	55	1.127	1.030	2281.97	0.078	0.763
6	0.215	0.224	526.23	0.015	0.139	56	3.283	2.150	3120.16	0.228	2.441
7	0.345	0.360	804.11	0.024	0.224	57	0.841	1.083	1796.61	0.058	0.557
8	0.387	0.437	892.23	0.027	0.251	58	NC	NC	NC	NC	NC
9	0.730	1.159	1591.43	0.051	0.478	59	3.199	1.713	3111.54	0.222	2.383
10	0.643	0.881	1421.42	0.045	0.417	60	1.027	0.848	2122.58	0.071	0.689
11	0.354	0.390	822.81	0.025	0.229	61	0.896	0.817	1897.91	0.062	0.596
12	0.478	0.504	1082.51	0.033	0.310	62	2.447	2.105	3083.90	0.170	1.817
13	0.857	0.802	1826.43	0.060	0.569	63	2.571	1.197	3087.85	0.179	1.911
14	0.896	0.752	1896.80	0.062	0.596	64	1.716	1.348	2903.32	0.119	1.231
15	0.190	0.216	472.99	0.013	0.123	65	0.774	0.648	1673.62	0.054	0.510
16	0.489	0.498	1105.28	0.034	0.317	66	1.976	2.837	3010.49	0.137	1.443
17	0.442	0.475	1005.94	0.031	0.286	67	2.631	2.545	3090.88	0.183	1.955
18	0.541	0.614	1212.76	0.038	0.351	68	1.563	2.192	2811.96	0.109	1.105
19	0.940	0.711	1974.75	0.065	0.627	69	2.937	2.221	3106.03	0.204	2.185
20	1.101	0.854	2240.91	0.076	0.743	70	3.051	2.041	3113.41	0.212	2.271
21	0.904	0.784	1912.29	0.063	0.602	71	1.648	2.470	2869.02	0.115	1.175
22	1.142	1.130	2304.14	0.079	0.774	72	1.259	1.428	2469.57	0.088	0.867
23	0.498	0.557	1123.96	0.035	0.323	73	NC	NC	NC	NC	NC
24	0.256	0.289	614.19	0.018	0.165	74	2.135	1.934	3055.90	0.148	1.578
25	0.665	0.711	1465.70	0.046	0.432	75	3.147	2.205	3115.73	0.219	2.342
26	1.406	1.582	2664.11	0.098	0.979	76	1.232	1.188	2432.17	0.086	0.844
27	1.118	1.173	2267.76	0.078	0.756	77	5.100	1.777	3132.07	0.354	3.898
28	0.934	0.882	1964.10	0.065	0.623	78	2.669	1.870	3094.10	0.185	1.983
29	1.150	1.288	2315.50	0.080	0.780	79	2.690	3.186	3095.71	0.187	1.999
30	0.202	0.227	499.29	0.014	0.131	80	NC	NC	NC	NC	NC
31	1.553	1.110	2804.34	0.108	1.097	81	NC	NC	NC	NC	NC
32	1.098	1.509	2236.43	0.076	0.741	82	NC	NC	NC	NC	NC
33	0.660	0.675	1454.80	0.046	0.428	83	2.960	4.500	3107.39	0.206	2.203
34	0.675	0.827	1485.85	0.047	0.439	84	1.573	2.288	2819.48	0.109	1.113
35	0.710	0.553	1553.86	0.049	0.464	85	2.296	3.094	3078.15	0.160	1.702
36	0.984	1.271	2051.61	0.068	0.658	86	1.845	1.299	2964.43	0.128	1.335
37	1.612	2.186	2845.27	0.112	1.145	87	NC	NC	NC	NC	NC
38	1.258	0.937	2467.79	0.087	0.866	88	3.032	3.222	3111.73	0.211	2.258
39	0.480	0.540	1085.89	0.033	0.311	89	2.743	2.377	3099.13	0.191	2.038
40	1.128	1.086	2284.03	0.078	0.764	90	2.668	3.251	3094.06	0.185	1.983
41	1.517	1.562	2775.81	0.105	1.068	91	NC	NC	NC	NC	NC
42	1.135	1.423	2293.48	0.079	0.769	92	1.955	1.944	3004.31	0.136	1.425
43	2.111	2.049	3049.05	0.147	1.558	93	4.324	2.813	3121.06	0.300	3.267
44	1.099	1.221	2237.81	0.076	0.742	94	NC	NC	NC	NC	NC
45	1.658	1.133	2874.48	0.115	1.182	95	2.832	2.835	3098.20	0.197	2.104
46	0.603	0.711	1339.67	0.042	0.391	96	2.055	2.511	3032.12	0.143	1.510
47	0.660	0.678	1456.08	0.046	0.429	97	2.186	4.267	3067.98	0.152	1.618
48	0.835	0.879	1785.50	0.058	0.553	98	2.378	3.133	3081.17	0.165	1.766
49	1.099	1.272	2237.65	0.076	0.742	99	NC	NC	NC	NC	NC
50	2.100	1.437	3045.79	0.146	1.549	100	2.845	4.092	3099.19	0.198	2.114

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.22 Results of SDOF Analyses of Frame ‘F5S7B’

(ATC Idealization Method)

EQ	ATC					EQ	ATC				
	μ_{ATC}	R_{ATC}	V (kN)	Δ (m)	MIDR (%)		μ_{ATC}	R_{ATC}	V (kN)	Δ (m)	MIDR (%)
1	0.029	0.029	81.60	0.002	0.018	51	1.038	1.037	2139.76	0.072	0.697
2	0.030	0.030	86.01	0.002	0.019	52	2.522	2.471	3086.79	0.175	1.875
3	0.173	0.173	435.69	0.012	0.112	53	0.633	0.633	1400.51	0.044	0.411
4	0.091	0.091	246.62	0.006	0.058	54	1.330	1.258	2565.33	0.092	0.921
5	0.171	0.171	430.98	0.012	0.111	55	1.031	1.030	2129.33	0.072	0.692
6	0.224	0.224	546.38	0.016	0.145	56	3.101	2.150	3115.81	0.216	2.309
7	0.360	0.360	835.89	0.025	0.233	57	1.088	1.083	2220.00	0.076	0.733
8	0.437	0.437	995.96	0.030	0.283	58	NC	NC	NC	NC	NC
9	1.121	1.159	2273.20	0.078	0.759	59	2.501	1.713	3085.31	0.174	1.859
10	0.881	0.881	1870.44	0.061	0.586	60	0.848	0.848	1810.47	0.059	0.562
11	0.390	0.390	898.17	0.027	0.253	61	0.817	0.817	1752.19	0.057	0.540
12	0.504	0.504	1135.29	0.035	0.327	62	2.784	2.105	3098.51	0.193	2.068
13	0.802	0.802	1724.03	0.056	0.529	63	1.195	1.197	2382.02	0.083	0.815
14	0.752	0.752	1631.49	0.052	0.493	64	1.440	1.348	2703.90	0.100	1.005
15	0.216	0.216	528.91	0.015	0.140	65	0.648	0.648	1432.65	0.045	0.421
16	0.498	0.498	1123.98	0.035	0.323	66	2.448	2.837	3083.89	0.170	1.818
17	0.475	0.475	1075.54	0.033	0.308	67	2.803	2.545	3097.87	0.195	2.082
18	0.614	0.614	1362.84	0.043	0.399	68	1.894	2.192	2983.98	0.132	1.375
19	0.711	0.711	1555.78	0.049	0.465	69	3.064	2.221	3114.31	0.213	2.280
20	0.854	0.854	1821.69	0.059	0.567	70	2.320	2.041	3078.80	0.161	1.720
21	0.784	0.784	1691.58	0.054	0.516	71	1.635	2.470	2860.53	0.114	1.164
22	1.142	1.130	2304.67	0.079	0.775	72	1.526	1.428	2783.20	0.106	1.075
23	0.557	0.557	1244.14	0.039	0.361	73	NC	NC	NC	NC	NC
24	0.289	0.289	685.25	0.020	0.187	74	1.840	1.934	2962.28	0.128	1.330
25	0.711	0.711	1554.49	0.049	0.464	75	2.243	2.205	3074.35	0.156	1.663
26	1.276	1.582	2492.84	0.089	0.880	76	1.208	1.188	2398.78	0.084	0.825
27	1.188	1.173	2371.25	0.083	0.809	77	3.824	1.777	3110.68	0.266	2.862
28	0.882	0.882	1873.04	0.061	0.587	78	2.765	1.870	3099.86	0.192	2.054
29	1.349	1.288	2590.36	0.094	0.935	79	2.145	3.186	3058.47	0.149	1.585
30	0.227	0.227	552.17	0.016	0.147	80	NC	NC	NC	NC	NC
31	1.119	1.110	2269.11	0.078	0.757	81	NC	NC	NC	NC	NC
32	1.332	1.509	2567.92	0.093	0.922	82	NC	NC	NC	NC	NC
33	0.675	0.675	1484.39	0.047	0.439	83	3.253	4.500	3117.51	0.226	2.420
34	0.826	0.826	1770.20	0.057	0.547	84	1.859	2.288	2970.13	0.129	1.346
35	0.553	0.553	1237.21	0.038	0.359	85	2.247	3.094	3073.97	0.156	1.665
36	1.315	1.271	2545.23	0.091	0.909	86	1.368	1.299	2616.28	0.095	0.950
37	2.065	2.186	3035.60	0.144	1.519	87	NC	NC	NC	NC	NC
38	0.937	0.937	1969.31	0.065	0.625	88	3.004	3.222	3109.79	0.209	2.236
39	0.540	0.540	1209.32	0.038	0.350	89	1.877	2.377	2977.51	0.130	1.361
40	1.093	1.086	2228.64	0.076	0.737	90	2.569	3.251	3087.90	0.179	1.909
41	1.512	1.562	2771.65	0.105	1.063	91	NC	NC	NC	NC	NC
42	1.350	1.423	2592.29	0.094	0.936	92	2.113	1.944	3049.86	0.147	1.560
43	1.675	2.049	2883.56	0.116	1.197	93	3.195	2.813	3111.28	0.222	2.380
44	1.249	1.221	2455.26	0.087	0.858	94	NC	NC	NC	NC	NC
45	1.159	1.133	2329.54	0.081	0.787	95	3.798	2.835	3111.49	0.264	2.840
46	0.711	0.711	1555.69	0.049	0.465	96	3.918	2.511	3113.54	0.272	2.938
47	0.678	0.678	1491.55	0.047	0.441	97	2.886	4.267	3102.93	0.201	2.146
48	0.879	0.879	1867.71	0.061	0.585	98	2.100	3.133	3045.95	0.146	1.549
49	1.156	1.272	2324.36	0.080	0.785	99	NC	NC	NC	NC	NC
50	1.621	1.437	2851.24	0.113	1.152	100	3.922	4.092	3113.69	0.273	2.941

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.23 Results of SDOF Analyses of Frame 'F5S7B'

(FEMA Idealization Method)

EQ	FEMA					EQ	FEMA				
	μ_{FEMA}	R_{FEMA}	V (kN)	Δ (m)	MIDR (%)		μ_{FEMA}	R_{FEMA}	V (kN)	Δ (m)	MIDR (%)
1	0.020	0.020	78.31	0.002	0.018	51	1.165	1.262	2856.78	0.113	1.159
2	0.033	0.033	133.75	0.003	0.030	52	1.741	1.585	3083.64	0.169	1.808
3	0.158	0.158	540.07	0.015	0.143	53	0.521	0.521	1588.47	0.051	0.477
4	0.065	0.065	246.06	0.006	0.058	54	1.062	1.058	2748.21	0.103	1.041
5	0.136	0.136	471.28	0.013	0.123	55	0.872	0.872	2415.39	0.085	0.834
6	0.118	0.118	415.93	0.011	0.106	56	2.380	2.130	3123.80	0.231	2.474
7	0.332	0.332	1052.60	0.032	0.301	57	0.737	0.737	2127.44	0.072	0.692
8	0.418	0.418	1301.49	0.041	0.379	58	NC	NC	NC	NC	NC
9	0.587	0.587	1760.34	0.057	0.543	59	2.305	1.700	3114.48	0.224	2.399
10	0.449	0.449	1391.74	0.044	0.408	60	0.832	0.832	2335.70	0.081	0.791
11	0.270	0.270	871.44	0.026	0.244	61	0.755	0.755	2168.09	0.073	0.710
12	0.450	0.450	1393.00	0.044	0.408	62	2.180	1.984	3113.26	0.212	2.270
13	0.730	0.730	2111.13	0.071	0.684	63	2.161	1.745	3110.71	0.210	2.250
14	0.804	0.804	2277.40	0.078	0.761	64	1.258	1.221	2922.18	0.122	1.264
15	0.143	0.143	494.90	0.014	0.130	65	0.546	0.546	1653.71	0.053	0.502
16	0.410	0.410	1279.63	0.040	0.372	66	2.143	1.484	3109.43	0.208	2.231
17	0.444	0.444	1377.79	0.043	0.403	67	2.429	2.066	3127.69	0.236	2.523
18	0.464	0.464	1432.40	0.045	0.421	68	1.370	1.468	2991.75	0.133	1.393
19	0.845	0.845	2362.91	0.082	0.805	69	2.596	2.073	3127.39	0.252	2.702
20	0.818	0.818	2306.70	0.079	0.776	70	2.311	1.854	3115.38	0.225	2.405
21	0.814	0.814	2299.01	0.079	0.772	71	1.285	1.391	2941.63	0.125	1.296
22	0.896	0.896	2461.48	0.087	0.862	72	0.913	0.913	2494.42	0.089	0.881
23	0.492	0.492	1509.72	0.048	0.448	73	NC	NC	NC	NC	NC
24	0.253	0.253	823.47	0.025	0.230	74	1.457	1.558	3026.76	0.142	1.496
25	0.501	0.501	1536.22	0.049	0.457	75	2.423	1.747	3127.10	0.235	2.517
26	1.169	1.381	2860.18	0.114	1.163	76	1.020	1.048	2688.69	0.099	0.995
27	0.828	0.828	2327.44	0.080	0.786	77	4.203	2.199	3182.87	0.408	4.519
28	0.665	0.665	1957.38	0.065	0.620	78	2.027	1.595	3098.39	0.197	2.106
29	0.911	0.911	2489.41	0.089	0.878	79	1.844	2.759	3087.57	0.179	1.917
30	0.200	0.200	665.64	0.019	0.181	80	NC	NC	NC	NC	NC
31	1.468	1.378	3031.72	0.143	1.509	81	NC	NC	NC	NC	NC
32	0.942	0.942	2548.42	0.092	0.911	82	NC	NC	NC	NC	NC
33	0.480	0.480	1477.86	0.047	0.437	83	2.438	4.293	3128.42	0.237	2.533
34	0.436	0.436	1354.69	0.042	0.396	84	1.358	1.515	2985.65	0.132	1.379
35	0.681	0.681	1997.84	0.066	0.636	85	1.856	1.844	3088.27	0.180	1.929
36	0.815	0.815	2301.57	0.079	0.773	86	1.369	1.512	2991.32	0.133	1.392
37	1.296	1.554	2949.15	0.126	1.308	87	NC	NC	NC	NC	NC
38	1.163	1.242	2854.47	0.113	1.156	88	2.450	2.595	3129.14	0.238	2.545
39	0.337	0.337	1066.62	0.033	0.305	89	1.696	2.014	3080.65	0.165	1.760
40	0.907	0.907	2481.47	0.088	0.874	90	2.164	2.261	3111.12	0.210	2.253
41	1.598	1.537	3074.57	0.155	1.657	91	NC	NC	NC	NC	NC
42	0.841	0.841	2354.19	0.082	0.800	92	1.378	1.928	2995.40	0.134	1.402
43	1.769	1.558	3084.54	0.172	1.838	93	3.132	2.821	3121.28	0.304	3.314
44	0.927	0.927	2520.62	0.090	0.895	94	NC	NC	NC	NC	NC
45	1.485	1.441	3039.28	0.144	1.529	95	1.826	3.186	3088.11	0.178	1.899
46	0.425	0.425	1320.52	0.041	0.385	96	2.149	3.007	3109.88	0.209	2.238
47	0.501	0.501	1536.59	0.049	0.457	97	1.990	3.311	3098.51	0.193	2.068
48	0.717	0.717	2082.79	0.070	0.672	98	1.675	3.574	3079.35	0.163	1.738
49	0.971	0.971	2602.90	0.094	0.942	99	NC	NC	NC	NC	NC
50	1.582	1.733	3072.04	0.154	1.639	100	2.461	3.746	3129.71	0.239	2.557

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.24 Results of SDOF Analyses of Frame 'F5S7B'

(75%Vy Idealization Method)

EQ	75%Vy					EQ	75%Vy				
	$\mu_{75\%Vy}$	$R_{75\%Vy}$	V (kN)	Δ (m)	MIDR (%)		$\mu_{75\%Vy}$	$R_{75\%Vy}$	V (kN)	Δ (m)	MIDR (%)
1	0.022	0.022	95.18	0.002	0.022	51	1.178	1.282	2934.61	0.124	1.284
2	0.033	0.033	143.66	0.004	0.033	52	1.604	1.490	3084.42	0.169	1.803
3	0.152	0.152	560.31	0.016	0.149	53	0.490	0.490	1611.95	0.052	0.486
4	0.054	0.054	224.40	0.006	0.052	54	1.055	1.052	2836.27	0.111	1.133
5	0.127	0.127	478.64	0.013	0.125	55	0.807	0.807	2418.76	0.085	0.836
6	0.102	0.102	393.08	0.011	0.100	56	2.233	2.092	3126.73	0.235	2.511
7	0.338	0.338	1151.43	0.036	0.332	57	0.632	0.632	2003.39	0.066	0.638
8	0.372	0.372	1256.56	0.039	0.365	58	NC	NC	NC	NC	NC
9	0.502	0.502	1646.95	0.053	0.499	59	2.271	1.700	3129.54	0.239	2.553
10	0.345	0.345	1174.33	0.036	0.339	60	0.884	0.884	2576.56	0.093	0.927
11	0.239	0.239	840.35	0.025	0.235	61	0.701	0.701	2177.20	0.074	0.714
12	0.478	0.478	1577.95	0.050	0.473	62	2.031	1.874	3114.77	0.214	2.288
13	0.748	0.748	2289.29	0.079	0.767	63	2.172	1.780	3120.65	0.229	2.445
14	0.804	0.804	2410.95	0.085	0.832	64	1.213	1.186	2960.10	0.128	1.327
15	0.138	0.138	514.05	0.015	0.135	65	0.566	0.566	1826.18	0.060	0.568
16	0.394	0.394	1326.21	0.041	0.387	66	1.653	1.340	3085.34	0.174	1.860
17	0.453	0.453	1505.97	0.048	0.447	67	2.194	1.902	3123.27	0.231	2.469
18	0.395	0.395	1327.90	0.042	0.388	68	1.203	1.307	2953.10	0.127	1.315
19	0.901	0.901	2609.91	0.095	0.946	69	2.516	1.759	3111.36	0.265	2.848
20	0.848	0.848	2503.19	0.089	0.886	70	2.306	1.814	3126.56	0.243	2.594
21	0.722	0.722	2228.40	0.076	0.737	71	1.113	1.172	2888.00	0.117	1.204
22	0.841	0.841	2488.48	0.088	0.877	72	0.917	0.917	2641.77	0.096	0.965
23	0.458	0.458	1520.05	0.048	0.452	73	NC	NC	NC	NC	NC
24	0.236	0.236	829.32	0.025	0.231	74	1.498	1.544	3075.57	0.158	1.681
25	0.536	0.536	1743.46	0.056	0.536	75	2.703	2.070	3111.71	0.284	3.076
26	1.164	1.324	2924.06	0.123	1.267	76	1.090	1.097	2870.16	0.115	1.176
27	0.757	0.757	2308.96	0.080	0.777	77	3.757	2.298	3177.42	0.395	4.368
28	0.678	0.678	2120.79	0.071	0.689	78	1.907	1.635	3102.94	0.201	2.146
29	0.905	0.905	2617.17	0.095	0.950	79	1.813	2.575	3099.17	0.191	2.039
30	0.165	0.165	600.62	0.017	0.161	80	NC	NC	NC	NC	NC
31	1.300	1.252	3008.32	0.137	1.437	81	NC	NC	NC	NC	NC
32	0.912	0.912	2632.24	0.096	0.959	82	NC	NC	NC	NC	NC
33	0.436	0.436	1455.82	0.046	0.429	83	2.111	4.118	3111.25	0.222	2.379
34	0.444	0.444	1479.93	0.047	0.437	84	1.194	1.224	2946.22	0.126	1.303
35	0.709	0.709	2195.75	0.075	0.722	85	1.851	1.730	3097.91	0.195	2.082
36	0.720	0.720	2223.01	0.076	0.735	86	1.352	1.540	3029.39	0.142	1.503
37	1.326	1.378	3019.60	0.139	1.470	87	NC	NC	NC	NC	NC
38	1.161	1.146	2921.72	0.122	1.264	88	2.175	2.445	3121.00	0.229	2.447
39	0.307	0.307	1054.14	0.032	0.301	89	1.672	2.011	3087.31	0.176	1.882
40	0.936	0.936	2676.67	0.098	0.987	90	1.973	2.107	3108.87	0.208	2.223
41	1.297	1.446	3006.80	0.136	1.433	91	NC	NC	NC	NC	NC
42	0.756	0.756	2307.44	0.080	0.776	92	1.399	1.815	3050.99	0.147	1.563
43	1.628	1.452	3084.42	0.171	1.831	93	3.151	2.810	3131.68	0.331	3.631
44	1.037	1.036	2817.34	0.109	1.111	94	NC	NC	NC	NC	NC
45	1.451	1.370	3069.62	0.153	1.626	95	1.787	2.862	3096.81	0.188	2.011
46	0.383	0.383	1290.78	0.040	0.376	96	1.756	3.003	3093.17	0.185	1.975
47	0.490	0.490	1613.41	0.052	0.486	97	2.168	2.627	3120.10	0.228	2.441
48	0.717	0.717	2217.20	0.075	0.732	98	1.794	2.825	3097.57	0.189	2.018
49	0.908	0.908	2623.90	0.096	0.954	99	NC	NC	NC	NC	NC
50	1.586	1.717	3083.13	0.167	1.783	100	1.919	3.323	3104.10	0.202	2.160

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.25 Results of SDOF Analyses of Frame 'F8S3B'

(MULTI Idealization Method)

EQ	MULTI					EQ	MULTI				
	μ_{MULTI}	R_{MULTI}	V (kN)	Δ (m)	MIDR (%)		μ_{MULTI}	R_{MULTI}	V (kN)	Δ (m)	MIDR (%)
1	0.034	0.034	115.24	0.005	0.020	51	1.920	1.895	3599.79	0.290	1.247
2	0.024	0.024	82.96	0.004	0.015	52	1.308	0.971	3259.63	0.197	0.797
3	0.177	0.177	563.81	0.027	0.106	53	0.916	0.865	2507.81	0.138	0.543
4	0.047	0.047	163.80	0.007	0.028	54	1.575	1.422	3432.64	0.238	0.996
5	0.081	0.081	277.20	0.012	0.048	55	1.585	1.628	3437.62	0.239	1.003
6	0.118	0.119	391.13	0.018	0.070	56	1.930	2.214	3603.80	0.291	1.254
7	0.290	0.297	874.06	0.044	0.173	57	1.206	1.122	3160.59	0.182	0.718
8	0.467	0.546	1343.08	0.070	0.278	58	2.027	1.906	3644.58	0.306	1.323
9	0.726	0.756	2019.78	0.110	0.431	59	4.341	2.876	4026.35	0.655	2.661
10	0.299	0.294	898.17	0.045	0.178	60	0.644	0.771	1805.80	0.097	0.383
11	0.276	0.260	836.89	0.042	0.165	61	1.309	1.357	3260.59	0.197	0.798
12	0.665	0.571	1860.31	0.100	0.395	62	1.023	1.156	2780.09	0.154	0.606
13	0.470	0.635	1353.37	0.071	0.280	63	1.626	2.217	3460.05	0.245	1.034
14	0.911	0.876	2494.63	0.137	0.540	64	2.233	1.444	3720.47	0.337	1.467
15	0.218	0.279	676.41	0.033	0.130	65	1.047	0.983	2841.04	0.158	0.620
16	0.638	0.532	1790.93	0.096	0.379	66	1.277	1.023	3233.51	0.193	0.773
17	0.888	0.841	2435.98	0.134	0.527	67	1.549	1.952	3418.43	0.234	0.977
18	0.297	0.337	893.19	0.045	0.177	68	2.180	2.443	3701.76	0.329	1.430
19	1.053	1.119	2856.09	0.159	0.624	69	2.092	3.182	3669.54	0.315	1.369
20	2.927	2.357	3890.27	0.441	1.905	70	2.184	3.214	3703.42	0.329	1.433
21	0.890	1.046	2441.96	0.134	0.528	71	0.761	0.888	2110.01	0.115	0.452
22	1.267	1.319	3224.97	0.191	0.765	72	1.785	1.694	3538.43	0.269	1.149
23	0.458	0.448	1320.94	0.069	0.273	73	3.028	2.749	3906.13	0.457	1.964
24	0.350	0.386	1033.75	0.053	0.208	74	1.207	1.446	3162.47	0.182	0.719
25	0.966	0.819	2637.05	0.146	0.573	75	2.267	1.655	3731.73	0.342	1.489
26	1.224	1.710	3183.11	0.185	0.730	76	1.145	1.355	3058.45	0.173	0.677
27	0.868	0.846	2385.04	0.131	0.515	77	NC	NC	NC	NC	NC
28	2.475	2.080	3797.61	0.373	1.630	78	1.748	2.813	3521.14	0.264	1.122
29	2.251	1.994	3726.44	0.339	1.479	79	1.075	1.158	2906.54	0.162	0.636
30	0.083	0.083	282.10	0.012	0.049	80	2.226	4.019	3717.84	0.336	1.461
31	1.211	1.251	3167.98	0.183	0.721	81	4.798	4.863	4055.98	0.724	2.896
32	1.641	1.388	3467.87	0.247	1.045	82	NC	NC	NC	NC	NC
33	0.265	0.262	807.42	0.040	0.158	83	1.551	2.124	3419.70	0.234	0.978
34	0.628	0.697	1763.86	0.095	0.373	84	1.032	0.931	2803.53	0.156	0.612
35	0.703	0.505	1960.67	0.106	0.418	85	1.616	2.271	3454.32	0.244	1.026
36	0.866	0.845	2379.34	0.131	0.514	86	1.826	1.874	3557.34	0.275	1.179
37	1.523	1.933	3404.36	0.230	0.957	87	2.666	2.202	3845.09	0.402	1.753
38	1.053	1.138	2857.68	0.159	0.624	88	2.522	2.828	3810.55	0.380	1.661
39	0.177	0.191	562.23	0.027	0.105	89	2.528	2.954	3811.97	0.381	1.665
40	2.902	1.792	3885.94	0.438	1.890	90	1.505	1.419	3394.02	0.227	0.944
41	1.528	1.443	3407.33	0.230	0.961	91	2.649	2.466	3841.13	0.399	1.742
42	0.401	0.385	1169.96	0.060	0.239	92	1.700	1.554	3497.54	0.256	1.087
43	1.586	1.215	3438.41	0.239	1.004	93	1.639	2.522	3466.45	0.247	1.043
44	1.760	2.351	3526.90	0.265	1.131	94	2.699	3.099	3851.79	0.407	1.772
45	1.806	1.697	3548.42	0.272	1.165	95	3.283	3.124	3939.34	0.495	2.107
46	0.361	0.315	1064.98	0.054	0.215	96	1.186	1.728	3128.70	0.179	0.704
47	1.079	0.900	2915.79	0.163	0.639	97	1.436	1.551	3352.68	0.217	0.893
48	1.223	0.999	3182.17	0.184	0.730	98	1.949	1.746	3611.99	0.294	1.267
49	1.085	0.952	2929.18	0.164	0.642	99	1.948	2.257	3611.72	0.294	1.267
50	1.715	1.552	3505.11	0.259	1.099	100	NC	NC	NC	NC	NC

V : Maximum Base Shear

Δ : Maximum Roof Displacement

MIDR : Maximum Inter-Story Drift Ratio

NC : Not Considered

Table A.3.26 Results of SDOF Analyses of Frame 'F8S3B'

(ATC Idealization Method)

EQ	ATC					EQ	ATC				
	μ_{ATC}	R_{ATC}	V (kN)	Δ (m)	MIDR (%)		μ_{ATC}	R_{ATC}	V (kN)	Δ (m)	MIDR (%)
1	0.034	0.034	115.23	0.005	0.020	51	1.578	1.895	3434.25	0.238	0.998
2	0.024	0.024	82.97	0.004	0.015	52	0.971	0.971	2649.06	0.146	0.576
3	0.177	0.177	563.11	0.027	0.106	53	0.865	0.865	2378.02	0.130	0.513
4	0.047	0.047	163.79	0.007	0.028	54	1.333	1.422	3279.15	0.201	0.816
5	0.081	0.081	277.14	0.012	0.048	55	1.344	1.628	3287.13	0.203	0.824
6	0.119	0.119	394.16	0.018	0.071	56	1.696	2.214	3495.65	0.256	1.085
7	0.297	0.297	891.78	0.045	0.177	57	1.104	1.122	2971.82	0.166	0.652
8	0.547	0.547	1552.86	0.082	0.325	58	1.466	1.906	3371.11	0.221	0.915
9	0.756	0.756	2096.88	0.114	0.449	59	4.080	2.876	4007.57	0.615	2.526
10	0.294	0.294	885.36	0.044	0.176	60	0.772	0.772	2136.67	0.116	0.458
11	0.260	0.260	791.82	0.039	0.155	61	1.448	1.357	3360.18	0.218	0.902
12	0.571	0.571	1617.06	0.086	0.340	62	1.092	1.156	2945.10	0.165	0.646
13	0.635	0.635	1782.73	0.096	0.377	63	2.152	2.217	3691.82	0.324	1.411
14	0.876	0.876	2405.59	0.132	0.520	64	1.648	1.444	3471.16	0.248	1.050
15	0.279	0.279	843.77	0.042	0.166	65	0.983	0.983	2678.91	0.148	0.583
16	0.532	0.532	1514.71	0.080	0.317	66	1.023	1.023	2781.66	0.154	0.607
17	0.841	0.841	2316.69	0.127	0.499	67	1.635	1.952	3464.56	0.247	1.040
18	0.337	0.337	1000.24	0.051	0.201	68	1.620	2.443	3456.75	0.244	1.029
19	1.132	1.119	3032.05	0.171	0.668	69	2.096	3.182	3671.18	0.316	1.372
20	2.264	2.357	3730.84	0.341	1.487	70	2.246	3.214	3724.74	0.339	1.475
21	1.048	1.046	2843.53	0.158	0.621	71	0.888	0.888	2435.48	0.134	0.527
22	1.150	1.320	3067.71	0.173	0.680	72	1.733	1.694	3514.05	0.261	1.112
23	0.448	0.448	1293.28	0.067	0.267	73	2.453	2.749	3791.33	0.370	1.615
24	0.386	0.386	1130.76	0.058	0.230	74	1.210	1.446	3165.93	0.182	0.720
25	0.819	0.819	2258.53	0.123	0.486	75	2.359	1.655	3762.10	0.356	1.552
26	1.401	1.710	3328.60	0.211	0.867	76	1.328	1.355	3275.12	0.200	0.812
27	0.846	0.846	2327.28	0.128	0.502	77	NC	NC	NC	NC	NC
28	2.254	2.080	3727.50	0.340	1.481	78	1.642	2.813	3468.15	0.248	1.045
29	1.637	1.994	3465.77	0.247	1.042	79	1.131	1.158	3031.52	0.171	0.668
30	0.083	0.083	282.11	0.012	0.049	80	2.612	4.019	3832.61	0.394	1.719
31	1.293	1.251	3247.39	0.195	0.786	81	4.308	4.863	4024.11	0.650	2.644
32	1.255	1.388	3214.19	0.189	0.756	82	NC	NC	NC	NC	NC
33	0.262	0.262	797.48	0.039	0.156	83	1.627	2.124	3460.44	0.245	1.035
34	0.697	0.697	1943.72	0.105	0.414	84	0.931	0.931	2547.32	0.140	0.552
35	0.505	0.505	1443.95	0.076	0.301	85	1.716	2.271	3505.60	0.259	1.099
36	0.845	0.845	2325.64	0.127	0.501	86	1.947	1.875	3611.48	0.294	1.267
37	1.315	1.933	3265.28	0.198	0.802	87	2.526	2.203	3811.44	0.381	1.663
38	1.057	1.138	2866.58	0.159	0.626	88	1.972	2.828	3621.98	0.297	1.284
39	0.191	0.191	602.56	0.029	0.114	89	2.069	2.954	3660.88	0.312	1.353
40	2.241	1.792	3723.24	0.338	1.472	90	1.715	1.419	3504.99	0.259	1.098
41	1.300	1.442	3252.87	0.196	0.791	91	2.952	2.466	3894.24	0.445	1.919
42	0.385	0.385	1126.51	0.058	0.229	92	1.688	1.554	3491.60	0.255	1.079
43	1.242	1.215	3201.80	0.187	0.745	93	1.946	2.523	3611.03	0.293	1.266
44	1.626	2.351	3459.70	0.245	1.034	94	2.199	3.099	3708.45	0.332	1.443
45	1.598	1.696	3445.02	0.241	1.013	95	3.761	3.124	3987.22	0.567	2.363
46	0.315	0.315	940.70	0.047	0.188	96	1.311	1.729	3262.02	0.198	0.799
47	0.900	0.900	2467.80	0.136	0.534	97	1.794	1.551	3542.95	0.271	1.156
48	0.999	0.999	2719.55	0.151	0.592	98	2.039	1.746	3649.11	0.307	1.332
49	0.952	0.952	2600.17	0.144	0.565	99	1.970	2.258	3621.19	0.297	1.283
50	1.781	1.552	3536.52	0.269	1.146	100	NC	NC	NC	NC	NC

V : Maximum Base Shear

Δ : Maximum Roof Displacement

MIDR : Maximum Inter-Story Drift Ratio

NC : Not Considered

Table A.3.27 Results of SDOF Analyses of Frame ‘F8S3B’

(FEMA Idealization Method)

EQ	FEMA					EQ	FEMA				
	μ_{FEMA}	R_{FEMA}	V (kN)	Δ (m)	MIDR (%)		μ_{FEMA}	R_{FEMA}	V (kN)	Δ (m)	MIDR (%)
1	0.031	0.031	139.13	0.006	0.024	51	1.513	1.808	3630.58	0.300	1.299
2	0.025	0.025	112.00	0.005	0.020	52	1.023	1.023	3289.44	0.203	0.826
3	0.141	0.141	586.62	0.028	0.111	53	0.810	0.810	2886.66	0.161	0.631
4	0.038	0.038	170.64	0.007	0.029	54	1.094	1.087	3355.41	0.217	0.896
5	0.095	0.095	410.59	0.019	0.074	55	1.244	1.635	3466.18	0.247	1.043
6	0.126	0.126	532.35	0.025	0.099	56	1.679	1.866	3712.49	0.333	1.451
7	0.225	0.225	889.25	0.045	0.176	57	1.124	1.146	3379.17	0.223	0.925
8	0.440	0.440	1639.18	0.087	0.345	58	1.526	1.920	3637.28	0.303	1.311
9	0.647	0.647	2341.52	0.128	0.505	59	3.624	2.465	4054.22	0.719	2.882
10	0.212	0.212	843.31	0.042	0.166	60	0.527	0.527	1934.08	0.105	0.412
11	0.240	0.240	943.51	0.048	0.188	61	1.007	1.007	3273.16	0.200	0.810
12	0.680	0.680	2455.61	0.135	0.531	62	0.904	0.904	3134.77	0.179	0.707
13	0.354	0.354	1342.06	0.070	0.278	63	1.441	1.579	3589.77	0.286	1.231
14	0.835	0.835	2962.09	0.166	0.650	64	1.557	1.399	3653.33	0.309	1.339
15	0.279	0.279	1080.99	0.055	0.219	65	0.910	0.910	3148.56	0.181	0.713
16	0.568	0.568	2073.46	0.113	0.444	66	1.088	1.086	3350.21	0.216	0.890
17	0.844	0.844	2987.82	0.168	0.656	67	1.355	1.452	3537.73	0.269	1.148
18	0.250	0.250	978.21	0.050	0.196	68	1.847	2.505	3784.69	0.367	1.600
19	0.793	0.793	2832.87	0.157	0.618	69	1.680	2.497	3712.97	0.334	1.452
20	2.070	2.297	3854.97	0.411	1.786	70	1.913	2.463	3809.51	0.380	1.659
21	0.759	0.759	2721.61	0.151	0.593	71	0.680	0.680	2453.56	0.135	0.531
22	1.102	1.096	3361.77	0.219	0.904	72	1.566	1.467	3657.71	0.311	1.347
23	0.430	0.430	1602.57	0.085	0.336	73	2.480	1.901	3937.30	0.492	2.097
24	0.316	0.316	1208.11	0.063	0.247	74	1.076	1.073	3338.89	0.214	0.878
25	0.808	0.808	2880.00	0.160	0.630	75	2.351	2.041	3916.08	0.467	2.002
26	1.106	1.135	3364.71	0.220	0.907	76	1.017	1.017	3283.79	0.202	0.820
27	0.740	0.740	2655.40	0.147	0.577	77	NC	NC	NC	NC	NC
28	2.066	2.019	3855.76	0.410	1.784	78	1.527	2.276	3638.00	0.303	1.312
29	1.848	1.860	3785.12	0.367	1.601	79	0.825	0.825	2932.46	0.164	0.643
30	0.053	0.053	240.01	0.011	0.041	80	1.811	3.133	3769.95	0.359	1.569
31	1.091	1.084	3352.81	0.217	0.893	81	4.118	3.493	4090.93	0.818	3.213
32	1.421	1.362	3577.90	0.282	1.211	82	NC	NC	NC	NC	NC
33	0.192	0.192	771.70	0.038	0.151	83	1.199	1.281	3434.31	0.238	0.998
34	0.510	0.510	1875.76	0.101	0.398	84	0.922	0.922	3171.65	0.183	0.723
35	0.647	0.647	2342.22	0.128	0.505	85	1.388	1.462	3557.93	0.275	1.179
36	0.696	0.696	2506.71	0.138	0.543	86	1.412	1.379	3572.42	0.280	1.202
37	1.302	1.526	3504.45	0.258	1.098	87	1.997	1.779	3836.37	0.396	1.729
38	0.903	0.903	3132.67	0.179	0.706	88	1.870	2.491	3793.52	0.371	1.621
39	0.150	0.150	619.66	0.030	0.118	89	1.943	2.750	3819.43	0.386	1.684
40	2.281	1.798	3902.37	0.453	1.949	90	1.280	1.372	3490.37	0.254	1.077
41	1.304	1.269	3505.90	0.259	1.100	91	1.973	1.815	3828.93	0.392	1.709
42	0.344	0.344	1305.40	0.068	0.269	92	1.325	1.292	3519.41	0.263	1.120
43	1.212	1.191	3443.59	0.241	1.011	93	1.274	1.681	3486.36	0.253	1.071
44	1.477	1.934	3610.38	0.293	1.265	94	2.554	3.305	3948.36	0.507	2.150
45	1.493	2.342	3619.07	0.296	1.279	95	2.559	2.423	3949.11	0.508	2.153
46	0.294	0.294	1134.54	0.058	0.231	96	0.912	0.912	3152.80	0.181	0.714
47	0.957	0.957	3218.25	0.190	0.759	97	1.279	1.216	3489.32	0.254	1.076
48	0.982	0.982	3246.37	0.195	0.785	98	1.356	1.452	3538.65	0.269	1.149
49	0.816	0.816	2905.06	0.162	0.636	99	1.470	1.566	3605.97	0.292	1.257
50	1.420	1.329	3577.39	0.282	1.210	100	NC	NC	NC	NC	NC

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

Table A.3.28 Results of SDOF Analyses of Frame 'F8S3B'

(75%Vy Idealization Method)

EQ	75%Vy					EQ	75%Vy				
	$\mu_{75\%Vy}$	$R_{75\%Vy}$	V (kN)	Δ (m)	MIDR (%)		$\mu_{75\%Vy}$	$R_{75\%Vy}$	V (kN)	Δ (m)	MIDR (%)
1	0.030	0.030	140.64	0.006	0.024	51	1.503	1.799	3642.91	0.305	1.320
2	0.025	0.025	113.75	0.005	0.020	52	1.057	1.054	3343.23	0.214	0.882
3	0.138	0.138	588.04	0.028	0.111	53	0.798	0.798	2902.87	0.162	0.635
4	0.036	0.036	169.56	0.007	0.029	54	1.081	1.075	3364.06	0.219	0.907
5	0.094	0.094	414.84	0.019	0.075	55	1.268	1.606	3500.91	0.257	1.092
6	0.129	0.129	553.86	0.026	0.104	56	1.683	1.843	3731.17	0.342	1.488
7	0.219	0.219	885.61	0.044	0.176	57	1.113	1.122	3389.61	0.226	0.938
8	0.417	0.417	1592.31	0.085	0.334	58	1.597	1.932	3690.50	0.324	1.408
9	0.643	0.643	2377.35	0.130	0.513	59	3.596	2.435	4058.60	0.730	2.917
10	0.201	0.201	819.49	0.041	0.161	60	0.515	0.515	1932.66	0.104	0.411
11	0.238	0.238	956.80	0.048	0.191	61	0.971	0.971	3258.72	0.197	0.796
12	0.695	0.695	2557.83	0.141	0.555	62	0.881	0.881	3127.75	0.179	0.704
13	0.337	0.337	1307.62	0.068	0.270	63	1.383	1.539	3573.60	0.281	1.204
14	0.848	0.848	3050.99	0.172	0.674	64	1.555	1.397	3669.50	0.315	1.369
15	0.285	0.285	1124.38	0.058	0.229	65	0.897	0.897	3162.37	0.182	0.719
16	0.568	0.568	2117.14	0.115	0.454	66	1.091	1.088	3371.98	0.221	0.916
17	0.831	0.831	3004.56	0.169	0.661	67	1.316	1.418	3531.99	0.267	1.139
18	0.242	0.242	968.77	0.049	0.194	68	1.855	2.495	3803.30	0.376	1.644
19	0.809	0.809	2937.30	0.164	0.644	69	1.674	2.425	3726.92	0.340	1.480
20	2.057	2.283	3864.60	0.417	1.813	70	1.823	2.362	3791.40	0.370	1.616
21	0.736	0.736	2698.95	0.149	0.587	71	0.680	0.680	2505.22	0.138	0.543
22	1.080	1.076	3362.86	0.219	0.905	72	1.551	1.455	3667.81	0.315	1.366
23	0.424	0.424	1614.13	0.086	0.339	73	2.469	1.876	3943.57	0.501	2.128
24	0.324	0.324	1263.28	0.066	0.260	74	1.038	1.038	3325.91	0.211	0.864
25	0.803	0.803	2918.15	0.163	0.639	75	2.185	2.048	3892.24	0.443	1.912
26	1.078	1.074	3361.10	0.219	0.903	76	0.988	0.988	3275.86	0.200	0.813
27	0.730	0.730	2678.31	0.148	0.583	77	NC	NC	NC	NC	NC
28	2.034	2.006	3859.09	0.413	1.795	78	1.529	2.240	3656.32	0.310	1.345
29	1.828	1.825	3792.96	0.371	1.619	79	0.811	0.811	2945.36	0.165	0.646
30	0.052	0.052	240.40	0.011	0.042	80	1.787	3.085	3776.66	0.363	1.583
31	1.048	1.046	3335.33	0.213	0.874	81	4.084	3.443	4094.67	0.829	3.251
32	1.364	1.343	3562.07	0.277	1.186	82	NC	NC	NC	NC	NC
33	0.193	0.193	790.48	0.039	0.155	83	1.171	1.229	3433.00	0.238	0.997
34	0.498	0.498	1874.89	0.101	0.398	84	0.890	0.890	3147.03	0.181	0.712
35	0.650	0.650	2400.05	0.132	0.518	85	1.320	1.386	3534.17	0.268	1.142
36	0.683	0.683	2514.12	0.139	0.545	86	1.378	1.341	3570.41	0.280	1.199
37	1.309	1.480	3527.50	0.266	1.132	87	1.962	1.756	3839.09	0.398	1.736
38	0.886	0.886	3139.20	0.180	0.709	88	1.884	2.450	3813.76	0.382	1.669
39	0.145	0.145	613.72	0.029	0.116	89	1.937	2.724	3831.21	0.393	1.715
40	2.286	1.794	3913.36	0.464	1.992	90	1.255	1.353	3491.91	0.255	1.079
41	1.264	1.236	3497.93	0.256	1.088	91	1.907	1.770	3821.63	0.387	1.689
42	0.333	0.333	1294.42	0.068	0.267	92	1.303	1.274	3523.64	0.264	1.126
43	1.209	1.188	3459.93	0.245	1.034	93	1.270	1.627	3502.23	0.258	1.094
44	1.439	1.896	3606.53	0.292	1.258	94	2.575	3.250	3960.35	0.522	2.207
45	1.503	2.338	3642.65	0.305	1.320	95	2.434	2.352	3938.47	0.494	2.102
46	0.292	0.292	1147.73	0.059	0.234	96	0.915	0.915	3190.56	0.186	0.736
47	0.955	0.955	3240.07	0.194	0.779	97	1.246	1.194	3485.97	0.253	1.071
48	0.985	0.985	3273.06	0.200	0.810	98	1.401	1.479	3584.11	0.284	1.221
49	0.807	0.807	2931.27	0.164	0.642	99	1.436	1.517	3604.84	0.291	1.255
50	1.371	1.297	3566.12	0.278	1.192	100	NC	NC	NC	NC	NC

V : Maximum Base Shear
Δ : Maximum Roof Displacement
MIDR : Maximum Inter-Story Drift Ratio
NC : Not Considered

A.4 COMPARISON RESULTS OF APPROXIMATIONS

Table A.4.1 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Top Displacement for Frame 'F2S2B'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	1.175	1.175	1.121	1.015	51	0.810	0.653	0.871	1.197
2	1.001	1.001	0.980	1.137	52	1.056	0.967	1.119	1.254
3	0.938	1.083	1.095	1.298	53	0.904	0.869	0.934	1.037
4	1.003	1.003	1.497	1.672	54	0.923	0.892	0.882	0.934
5	1.047	1.054	1.271	1.455	55	0.974	1.141	0.891	1.149
6	0.933	0.995	1.010	0.943	56	0.990	0.935	1.048	1.223
7	0.939	1.021	1.005	1.297	57	0.912	1.010	1.180	1.207
8	0.858	0.824	0.969	0.973	58	0.959	0.694	0.805	0.948
9	0.901	0.881	1.158	1.193	59	0.906	0.799	0.873	0.963
10	0.851	0.789	1.104	1.130	60	0.898	0.846	1.043	1.340
11	0.832	0.763	1.078	1.119	61	0.762	0.729	0.949	1.252
12	0.805	0.860	0.947	1.198	62	0.957	1.035	1.172	1.246
13	0.983	1.024	0.999	1.077	63	0.734	0.485	0.624	1.182
14	0.752	0.850	0.848	1.123	64	0.909	0.844	0.881	0.966
15	0.850	0.799	1.082	0.888	65	0.957	1.099	0.944	1.058
16	0.828	0.783	1.040	1.054	66	1.059	0.981	0.988	1.396
17	1.041	1.283	1.021	1.084	67	0.920	0.897	1.005	1.299
18	0.788	0.754	0.912	1.178	68	0.989	1.171	1.291	1.257
19	0.876	1.008	0.936	1.131	69	0.919	0.666	0.954	1.324
20	0.933	0.801	0.945	1.070	70	1.016	0.758	0.879	1.137
21	0.767	0.862	0.949	1.241	71	0.922	0.749	0.978	1.239
22	0.968	0.869	1.149	1.213	72	0.952	1.197	1.221	1.053
23	1.026	0.900	1.066	1.003	73	0.933	0.755	0.864	0.999
24	0.979	1.030	0.916	1.099	74	0.929	0.833	0.881	0.847
25	0.895	1.137	1.007	0.967	75	0.912	0.830	0.870	0.924
26	0.954	0.854	1.047	1.262	76	0.978	0.901	1.206	1.392
27	0.974	0.953	1.066	1.042	77	0.494	0.418	0.444	0.598
28	0.920	1.032	1.094	0.918	78	0.915	1.065	0.920	1.025
29	0.908	0.855	1.040	0.938	79	1.039	0.847	0.952	1.102
30	0.935	1.012	1.200	1.490	80	1.069	1.127	1.164	1.130
31	0.726	0.540	0.831	1.314	81	0.600	0.473	0.534	0.601
32	0.948	1.152	1.186	1.228	82	1.067	0.984	0.987	0.984
33	0.982	0.984	1.015	1.030	83	1.007	0.940	0.950	0.979
34	0.890	1.074	1.052	0.982	84	0.962	0.969	0.943	1.164
35	1.169	1.386	1.054	1.280	85	0.965	0.894	0.895	0.915
36	0.865	0.954	1.092	1.019	86	0.910	0.752	0.926	1.121
37	0.901	0.683	1.056	1.279	87	1.070	0.921	1.001	1.125
38	0.952	0.899	0.931	1.306	88	NC	NC	NC	NC
39	0.960	1.084	0.959	0.872	89	0.902	0.733	0.846	0.955
40	1.085	1.119	1.067	1.160	90	1.018	0.954	1.029	1.175
41	0.999	0.950	1.032	1.272	91	0.970	0.948	0.968	0.996
42	1.046	0.953	1.154	1.129	92	1.016	1.028	1.151	1.074
43	1.024	0.879	0.894	1.163	93	0.773	0.632	0.720	0.840
44	1.056	0.988	1.251	0.970	94	1.122	0.962	1.031	1.125
45	0.700	0.612	0.752	1.206	95	0.931	0.918	0.921	0.993
46	1.003	1.067	0.977	0.863	96	1.175	1.377	1.458	1.421
47	1.000	1.028	1.053	0.998	97	1.112	1.251	1.283	1.463
48	0.800	0.990	0.981	0.987	98	1.106	1.168	0.993	1.112
49	0.937	0.931	1.035	1.160	99	1.105	1.001	1.044	1.102
50	0.905	0.901	0.950	1.104	100	1.179	1.146	1.133	1.232

NC : Not Considered

Table A.4.2 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Inter-story Drift Ratio for Frame 'F2S2B'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	1.184	1.184	1.129	1.023	51	0.806	0.640	0.870	1.194
2	1.006	1.006	0.985	1.142	52	0.940	0.875	0.987	1.092
3	0.963	1.107	1.119	1.319	53	0.802	0.771	0.828	0.920
4	0.987	0.987	1.455	1.620	54	0.934	0.905	0.895	0.945
5	1.071	1.078	1.293	1.472	55	0.965	1.131	0.880	1.139
6	0.830	0.883	0.897	0.838	56	1.001	0.951	1.055	1.224
7	0.928	1.008	0.992	1.278	57	0.912	1.018	1.200	1.227
8	0.870	0.836	0.982	0.985	58	0.906	0.701	0.789	0.898
9	0.885	0.864	1.155	1.191	59	0.949	0.853	0.919	1.002
10	0.832	0.771	1.096	1.124	60	0.846	0.796	0.992	1.291
11	0.844	0.774	1.090	1.132	61	0.730	0.698	0.917	1.229
12	0.831	0.887	0.978	1.237	62	0.935	0.999	1.116	1.183
13	1.004	1.048	1.021	1.107	63	0.794	0.522	0.679	1.171
14	0.769	0.871	0.869	1.172	64	0.877	0.819	0.853	0.923
15	0.833	0.784	1.053	0.869	65	0.876	1.007	0.864	0.969
16	0.825	0.780	1.035	1.049	66	0.953	0.896	0.901	1.208
17	1.036	1.277	1.016	1.079	67	0.882	0.865	0.950	1.197
18	0.776	0.743	0.898	1.168	68	0.946	1.080	1.169	1.143
19	0.901	1.041	0.962	1.177	69	0.933	0.717	0.964	1.315
20	0.946	0.804	0.958	1.094	70	1.016	0.794	0.896	1.127
21	0.768	0.864	0.958	1.272	71	0.872	0.720	0.915	1.100
22	0.960	0.856	1.147	1.211	72	0.901	1.114	1.133	0.993
23	1.024	0.898	1.063	1.000	73	0.951	0.793	0.888	1.012
24	0.986	1.036	0.923	1.106	74	0.863	0.792	0.826	0.802
25	0.813	1.041	0.915	0.878	75	0.913	0.844	0.878	0.924
26	0.918	0.819	1.007	1.194	76	0.921	0.845	1.141	1.310
27	0.935	0.914	1.025	1.002	77	0.372	0.316	0.335	0.447
28	0.934	1.056	1.124	0.932	78	0.946	1.077	0.950	1.041
29	0.905	0.852	1.030	0.934	79	0.938	0.790	0.870	0.989
30	0.724	0.781	0.923	1.141	80	1.019	1.073	1.108	1.075
31	0.707	0.516	0.814	1.231	81	0.584	0.464	0.522	0.586
32	0.919	1.114	1.145	1.183	82	1.063	0.983	0.986	0.983
33	0.944	0.946	0.976	0.990	83	0.980	0.918	0.927	0.954
34	0.890	1.087	1.063	0.988	84	0.864	0.869	0.850	1.001
35	1.140	1.352	1.028	1.248	85	0.938	0.881	0.882	0.898
36	0.850	0.939	1.070	1.002	86	0.896	0.741	0.910	1.074
37	0.871	0.664	0.994	1.155	87	1.003	0.868	0.940	1.053
38	0.915	0.861	0.894	1.260	88	NC	NC	NC	NC
39	0.843	0.951	0.841	0.765	89	0.835	0.711	0.793	0.874
40	1.101	1.137	1.083	1.178	90	0.894	0.845	0.902	1.019
41	0.961	0.916	0.991	1.186	91	0.967	0.946	0.965	0.992
42	1.024	0.931	1.129	1.105	92	0.898	0.906	0.987	0.934
43	0.971	0.865	0.876	1.078	93	0.417	0.345	0.389	0.452
44	1.030	0.962	1.218	0.944	94	1.039	0.895	0.956	1.041
45	0.713	0.619	0.767	1.160	95	0.936	0.924	0.926	0.995
46	0.926	0.990	0.901	0.796	96	0.961	1.114	1.179	1.149
47	0.910	0.935	0.958	0.908	97	0.918	1.015	1.038	1.171
48	0.774	0.972	0.961	0.968	98	0.967	1.014	0.882	0.972
49	0.901	0.895	0.998	1.118	99	0.965	0.878	0.913	0.963
50	0.902	0.899	0.940	1.053	100	1.125	1.095	1.083	1.175

NC : Not Considered

Table A.4.3 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Base Shear for Frame 'F2S2B'

EQ	MULTI	ATC	FEMA	75%Vy
1	1.082	1.082	1.033	0.937
2	1.023	1.023	1.002	1.156
3	0.872	1.003	1.015	1.211
4	1.018	1.018	1.439	1.586
5	0.941	0.947	1.138	1.309
6	0.928	0.990	1.006	0.937
7	0.936	1.014	0.999	1.270
8	0.850	0.817	0.955	0.959
9	0.937	0.924	1.100	1.121
10	0.932	0.878	1.106	1.122
11	0.812	0.746	1.043	1.081
12	0.801	0.850	0.913	1.092
13	0.959	0.984	0.969	1.016
14	0.761	0.833	0.833	0.995
15	0.812	0.762	1.042	0.849
16	0.865	0.819	1.055	1.066
17	1.023	1.196	1.008	1.054
18	0.828	0.801	0.924	1.113
19	0.853	0.943	0.898	1.014
20	0.922	0.835	0.928	1.006
21	0.814	0.890	0.945	1.122
22	0.935	0.872	1.042	1.077
23	1.066	0.967	1.097	1.048
24	1.001	1.051	0.938	1.119
25	0.922	1.092	1.010	0.979
26	0.965	0.900	1.019	1.109
27	1.076	1.061	1.138	1.122
28	0.907	0.975	1.012	0.905
29	0.964	0.930	1.035	0.982
30	0.928	1.008	1.201	1.490
31	0.853	0.705	0.930	1.132
32	1.032	1.156	1.173	1.193
33	1.095	1.097	1.124	1.136
34	0.919	1.036	1.022	0.979
35	1.126	1.283	1.040	1.207
36	0.949	1.009	1.087	1.049
37	0.907	0.776	0.951	0.988
38	0.918	0.885	0.905	1.112
39	1.402	1.536	1.400	1.306
40	0.976	0.996	0.966	1.017
41	0.960	0.935	0.977	1.053
42	1.027	0.969	1.087	1.075
43	1.050	1.023	1.027	1.082
44	1.038	0.996	1.145	0.984
45	0.834	0.765	0.873	1.044
46	1.232	1.282	1.210	1.099
47	0.912	0.931	0.949	0.910
48	0.873	0.999	0.993	0.997
49	1.008	1.004	1.074	1.148
50	0.977	0.976	0.991	1.017
51	0.841	0.734	0.881	1.062
52	0.997	0.977	1.013	1.029
53	0.994	0.965	1.019	1.106
54	0.959	0.943	0.937	0.965
55	0.900	0.991	0.851	0.995
56	0.935	0.929	0.940	0.935
57	0.817	0.872	0.964	0.977
58	0.961	0.894	0.925	0.959
59	0.864	0.840	0.859	0.870
60	0.769	0.735	0.847	0.993
61	0.759	0.733	0.883	1.054
62	1.022	1.043	1.059	1.063
63	0.896	0.699	0.820	1.013
64	0.964	0.932	0.951	0.985
65	1.045	1.159	1.034	1.129
66	1.022	1.005	1.007	1.077
67	0.956	0.951	0.978	1.007
68	1.013	1.051	1.077	1.069
69	0.940	0.872	0.945	0.945
70	0.994	0.936	0.968	1.003
71	0.985	0.893	1.002	1.048
72	0.971	1.084	1.091	1.025
73	0.875	0.838	0.866	0.880
74	1.043	1.022	1.029	1.023
75	0.990	0.966	0.977	0.993
76	0.901	0.854	1.026	1.108
77	0.835	0.848	0.840	0.828
78	0.878	0.908	0.879	0.903
79	1.030	0.984	1.012	1.037
80	0.924	0.921	0.920	0.921
81	0.857	0.874	0.863	0.856
82	0.962	0.965	0.965	0.965
83	0.981	0.979	0.980	0.980
84	0.892	0.894	0.887	0.926
85	0.895	0.879	0.879	0.884
86	0.948	0.848	0.956	1.026
87	1.003	1.007	1.009	0.996
88	NC	NC	NC	NC
89	0.953	0.916	0.938	0.965
90	1.016	1.006	1.018	1.029
91	0.957	0.958	0.957	0.956
92	0.956	0.957	0.975	0.960
93	0.739	0.735	0.742	0.732
94	0.914	0.915	0.913	0.913
95	0.888	0.886	0.887	0.890
96	0.982	0.990	0.985	0.988
97	0.951	0.977	0.980	0.992
98	0.959	0.966	0.934	0.960
99	1.008	1.014	1.012	1.008
100	0.807	0.809	0.810	0.805

NC : Not Considered

Table A.4.4 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Top Displacement for Frame 'F2S2B'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	0.954	0.864	51	0.807	1.076	1.479
2	1.000	0.979	1.135	52	0.915	1.060	1.188
3	1.155	1.168	1.384	53	0.961	1.033	1.147
4	1.000	1.493	1.667	54	0.967	0.956	1.012
5	1.007	1.214	1.390	55	1.172	0.915	1.180
6	1.066	1.082	1.010	56	0.944	1.059	1.236
7	1.087	1.070	1.380	57	1.108	1.295	1.324
8	0.961	1.129	1.134	58	0.724	0.840	0.988
9	0.978	1.286	1.324	59	0.882	0.964	1.063
10	0.927	1.298	1.328	60	0.942	1.162	1.491
11	0.917	1.295	1.345	61	0.956	1.245	1.643
12	1.068	1.177	1.488	62	1.081	1.225	1.303
13	1.041	1.016	1.096	63	0.660	0.850	1.610
14	1.131	1.129	1.494	64	0.928	0.969	1.062
15	0.939	1.272	1.044	65	1.148	0.987	1.106
16	0.945	1.256	1.274	66	0.926	0.933	1.318
17	1.233	0.981	1.041	67	0.976	1.093	1.412
18	0.957	1.158	1.496	68	1.184	1.305	1.270
19	1.151	1.068	1.290	69	0.725	1.038	1.441
20	0.858	1.012	1.146	70	0.746	0.865	1.118
21	1.124	1.237	1.619	71	0.812	1.060	1.343
22	0.898	1.187	1.254	72	1.257	1.283	1.106
23	0.877	1.038	0.977	73	0.809	0.925	1.071
24	1.052	0.935	1.123	74	0.896	0.948	0.911
25	1.271	1.125	1.080	75	0.910	0.954	1.014
26	0.895	1.098	1.323	76	0.921	1.232	1.423
27	0.978	1.094	1.070	77	0.846	0.898	1.210
28	1.121	1.189	0.998	78	1.164	1.005	1.119
29	0.943	1.146	1.033	79	0.815	0.917	1.061
30	1.082	1.283	1.593	80	1.054	1.089	1.057
31	0.744	1.145	1.810	81	0.789	0.891	1.003
32	1.215	1.250	1.295	82	0.922	0.925	0.922
33	1.002	1.034	1.049	83	0.933	0.943	0.972
34	1.207	1.182	1.103	84	1.008	0.981	1.211
35	1.185	0.901	1.095	85	0.926	0.927	0.949
36	1.103	1.262	1.178	86	0.826	1.017	1.231
37	0.758	1.172	1.420	87	0.861	0.936	1.052
38	0.944	0.978	1.371	88	NC	NC	NC
39	1.129	0.998	0.908	89	0.813	0.938	1.059
40	1.032	0.984	1.069	90	0.937	1.011	1.154
41	0.951	1.033	1.273	91	0.978	0.999	1.027
42	0.911	1.103	1.079	92	1.011	1.133	1.057
43	0.858	0.873	1.137	93	0.817	0.931	1.086
44	0.936	1.184	0.919	94	0.858	0.919	1.003
45	0.874	1.074	1.722	95	0.986	0.989	1.067
46	1.064	0.974	0.861	96	1.172	1.241	1.209
47	1.027	1.052	0.998	97	1.126	1.155	1.317
48	1.238	1.226	1.234	98	1.056	0.898	1.006
49	0.994	1.105	1.238	99	0.906	0.945	0.998
50	0.996	1.050	1.220	100	0.972	0.961	1.045

NC : Not Considered

Table A.4.5 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Inter-story Drift Ratio for Frame 'F2S2B'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	0.954	0.864	51	0.795	1.080	1.482
2	1.000	0.979	1.135	52	0.931	1.050	1.161
3	1.150	1.162	1.370	53	0.961	1.033	1.147
4	1.000	1.475	1.642	54	0.969	0.958	1.011
5	1.007	1.207	1.375	55	1.173	0.912	1.181
6	1.064	1.081	1.010	56	0.950	1.054	1.223
7	1.086	1.070	1.377	57	1.116	1.315	1.346
8	0.961	1.129	1.133	58	0.774	0.870	0.991
9	0.976	1.305	1.345	59	0.899	0.968	1.056
10	0.927	1.318	1.351	60	0.941	1.173	1.526
11	0.918	1.292	1.341	61	0.956	1.256	1.682
12	1.068	1.176	1.488	62	1.069	1.194	1.265
13	1.044	1.017	1.103	63	0.658	0.855	1.474
14	1.133	1.131	1.525	64	0.934	0.972	1.053
15	0.941	1.264	1.043	65	1.150	0.987	1.106
16	0.946	1.255	1.273	66	0.940	0.946	1.268
17	1.233	0.981	1.041	67	0.980	1.076	1.356
18	0.957	1.158	1.505	68	1.142	1.236	1.208
19	1.156	1.068	1.307	69	0.769	1.033	1.409
20	0.850	1.013	1.156	70	0.782	0.882	1.109
21	1.125	1.247	1.657	71	0.825	1.049	1.261
22	0.892	1.194	1.261	72	1.237	1.258	1.102
23	0.877	1.038	0.977	73	0.834	0.934	1.064
24	1.051	0.936	1.121	74	0.919	0.958	0.930
25	1.281	1.125	1.080	75	0.925	0.961	1.012
26	0.892	1.096	1.300	76	0.917	1.239	1.422
27	0.978	1.095	1.071	77	0.850	0.901	1.202
28	1.130	1.203	0.997	78	1.138	1.004	1.100
29	0.942	1.139	1.033	79	0.843	0.928	1.054
30	1.079	1.275	1.577	80	1.053	1.087	1.055
31	0.730	1.151	1.741	81	0.794	0.893	1.003
32	1.213	1.246	1.288	82	0.925	0.927	0.925
33	1.002	1.034	1.049	83	0.937	0.946	0.973
34	1.222	1.195	1.110	84	1.006	0.984	1.160
35	1.186	0.901	1.095	85	0.939	0.940	0.957
36	1.105	1.259	1.180	86	0.828	1.017	1.199
37	0.763	1.141	1.326	87	0.865	0.937	1.050
38	0.941	0.977	1.377	88	NC	NC	NC
39	1.129	0.998	0.908	89	0.852	0.950	1.047
40	1.032	0.983	1.070	90	0.946	1.009	1.141
41	0.953	1.032	1.235	91	0.979	0.999	1.026
42	0.909	1.102	1.079	92	1.008	1.098	1.040
43	0.890	0.902	1.109	93	0.826	0.933	1.084
44	0.934	1.182	0.916	94	0.862	0.921	1.003
45	0.868	1.076	1.627	95	0.987	0.990	1.063
46	1.069	0.973	0.860	96	1.160	1.227	1.196
47	1.027	1.052	0.998	97	1.106	1.131	1.276
48	1.256	1.243	1.252	98	1.049	0.913	1.005
49	0.993	1.108	1.240	99	0.909	0.946	0.998
50	0.996	1.041	1.167	100	0.973	0.962	1.044

NC : Not Considered

Table A.4.6 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Base Shear for Frame 'F2S2B'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	0.955	0.866	51	0.873	1.048	1.263
2	1.000	0.979	1.130	52	0.980	1.016	1.032
3	1.151	1.164	1.389	53	0.971	1.025	1.112
4	1.000	1.414	1.558	54	0.983	0.977	1.006
5	1.007	1.209	1.390	55	1.101	0.945	1.105
6	1.067	1.084	1.010	56	0.993	1.006	1.000
7	1.083	1.068	1.357	57	1.067	1.179	1.196
8	0.962	1.124	1.128	58	0.930	0.963	0.998
9	0.986	1.174	1.196	59	0.972	0.994	1.007
10	0.943	1.186	1.204	60	0.955	1.100	1.291
11	0.918	1.284	1.331	61	0.966	1.164	1.390
12	1.061	1.140	1.362	62	1.020	1.036	1.040
13	1.026	1.010	1.059	63	0.780	0.915	1.130
14	1.095	1.094	1.308	64	0.966	0.987	1.021
15	0.939	1.284	1.046	65	1.109	0.990	1.081
16	0.947	1.221	1.233	66	0.983	0.985	1.053
17	1.170	0.986	1.030	67	0.995	1.023	1.053
18	0.968	1.117	1.345	68	1.038	1.064	1.056
19	1.105	1.052	1.188	69	0.928	1.005	1.005
20	0.906	1.007	1.091	70	0.941	0.974	1.009
21	1.093	1.160	1.377	71	0.907	1.017	1.064
22	0.933	1.115	1.152	72	1.116	1.123	1.056
23	0.907	1.029	0.983	73	0.958	0.990	1.007
24	1.050	0.937	1.118	74	0.980	0.987	0.981
25	1.184	1.095	1.062	75	0.976	0.987	1.004
26	0.933	1.055	1.149	76	0.948	1.140	1.231
27	0.986	1.057	1.043	77	1.016	1.006	0.993
28	1.075	1.116	0.998	78	1.033	1.001	1.027
29	0.965	1.074	1.019	79	0.955	0.982	1.007
30	1.086	1.294	1.605	80	0.997	0.996	0.997
31	0.827	1.090	1.327	81	1.020	1.007	0.999
32	1.120	1.137	1.156	82	1.002	1.002	1.002
33	1.002	1.026	1.038	83	0.999	0.999	1.000
34	1.127	1.112	1.065	84	1.002	0.994	1.037
35	1.140	0.924	1.072	85	0.981	0.982	0.987
36	1.063	1.145	1.105	86	0.895	1.009	1.083
37	0.856	1.049	1.090	87	1.004	1.006	0.993
38	0.964	0.986	1.212	88	NC	NC	NC
39	1.096	0.999	0.931	89	0.961	0.984	1.013
40	1.020	0.990	1.042	90	0.990	1.001	1.013
41	0.974	1.017	1.097	91	1.001	1.000	0.999
42	0.943	1.059	1.046	92	1.001	1.019	1.004
43	0.974	0.978	1.030	93	0.994	1.003	0.991
44	0.959	1.103	0.948	94	1.001	0.999	1.000
45	0.917	1.046	1.252	95	0.998	0.999	1.003
46	1.041	0.982	0.892	96	1.008	1.003	1.006
47	1.021	1.040	0.998	97	1.028	1.031	1.043
48	1.145	1.138	1.143	98	1.007	0.974	1.001
49	0.996	1.065	1.138	99	1.006	1.004	1.000
50	0.998	1.014	1.040	100	1.003	1.005	0.997

NC : Not Considered

Table A.4.7 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Top Displacement for Frame 'F2S2B2'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	1.141	1.141	1.193	1.215	51	0.874	0.864	0.946	0.974
2	1.186	1.186	1.258	1.296	52	0.980	1.037	1.022	1.013
3	1.161	1.161	1.099	1.068	53	0.805	0.700	0.818	0.859
4	1.061	1.061	1.056	1.067	54	0.917	0.844	0.940	0.973
5	0.956	0.956	0.958	0.959	55	1.135	1.231	1.251	1.233
6	1.002	1.105	1.098	1.098	56	0.920	0.950	0.939	0.974
7	0.922	0.946	0.980	0.990	57	0.721	0.698	0.808	0.870
8	0.844	0.852	0.963	0.989	58	0.710	0.635	0.760	0.811
9	0.887	0.884	0.977	1.013	59	0.942	0.916	0.955	0.967
10	0.950	0.941	0.994	1.014	60	0.983	0.999	1.019	1.027
11	0.984	1.004	0.984	0.973	61	0.909	0.918	1.003	1.023
12	0.993	1.057	1.033	1.016	62	0.690	0.629	0.678	0.710
13	0.874	0.865	0.959	0.984	63	0.988	1.018	1.011	1.014
14	0.798	0.796	0.840	0.883	64	0.886	0.865	0.923	0.940
15	1.059	1.077	1.088	1.073	65	0.980	0.884	0.923	0.944
16	0.965	0.969	1.018	1.042	66	0.652	0.575	0.706	0.776
17	0.852	0.859	0.940	0.957	67	1.092	1.152	1.097	1.080
18	1.212	1.211	1.090	1.031	68	0.955	0.830	0.906	0.928
19	1.010	1.157	1.096	1.065	69	0.843	0.731	0.801	0.822
20	1.029	1.024	1.007	1.006	70	0.971	0.996	1.017	1.009
21	0.865	0.850	0.921	0.942	71	0.832	0.758	0.849	0.877
22	0.915	0.915	0.962	0.979	72	0.772	0.740	0.868	0.900
23	0.912	0.916	1.043	1.072	73	0.960	1.012	1.024	1.026
24	0.761	0.751	0.880	0.928	74	0.904	0.832	0.886	0.913
25	0.935	0.959	0.952	0.937	75	1.036	1.044	1.081	1.069
26	0.986	0.979	1.072	1.095	76	0.988	1.026	1.128	1.113
27	0.928	0.920	0.961	0.977	77	0.923	0.921	0.933	0.934
28	1.053	1.134	1.137	1.116	78	1.182	1.099	1.147	1.210
29	0.877	0.912	0.952	0.971	79	0.833	0.821	0.915	0.979
30	0.932	0.967	1.003	1.013	80	0.811	0.670	0.797	0.857
31	0.910	0.918	0.964	0.995	81	0.870	0.783	0.881	0.922
32	0.716	0.689	0.769	0.828	82	0.907	0.885	0.971	1.008
33	0.894	0.872	0.932	0.953	83	0.988	0.833	0.872	0.885
34	0.864	0.853	0.931	0.962	84	0.899	0.881	0.916	0.934
35	0.960	1.002	0.948	0.934	85	0.923	0.957	1.094	1.128
36	0.934	0.908	0.943	0.956	86	1.066	1.225	1.189	1.107
37	1.121	1.235	1.203	1.162	87	0.828	0.740	0.807	0.833
38	0.982	1.003	1.022	1.027	88	0.820	0.787	0.845	0.872
39	1.079	1.055	1.160	1.166	89	0.897	0.840	0.927	0.964
40	0.866	0.844	0.925	0.954	90	0.893	0.886	0.932	0.938
41	0.979	1.061	0.997	0.983	91	0.931	0.866	0.880	0.883
42	0.747	0.768	0.820	0.832	92	0.986	1.047	1.035	1.014
43	0.929	0.958	0.991	1.006	93	0.862	0.826	0.883	0.901
44	1.131	1.274	1.219	1.196	94	0.624	0.616	0.653	0.655
45	0.878	0.901	0.951	0.981	95	0.794	0.735	0.784	0.813
46	0.977	1.045	1.109	1.119	96	0.823	0.852	0.826	0.787
47	1.074	1.161	1.177	1.160	97	0.942	0.949	0.938	0.948
48	0.994	0.984	1.084	1.137	98	0.985	1.031	0.997	0.986
49	0.873	0.841	0.906	0.929	99	1.005	1.084	1.091	1.073
50	0.954	0.999	1.039	1.055	100	0.900	0.823	0.843	0.858

NC : Not Considered

Table A.4.8 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Inter-story Drift Ratio for Frame 'F2S2B2'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	1.145	1.145	1.197	1.218	51	0.883	0.873	0.956	0.984
2	1.208	1.208	1.279	1.316	52	0.996	1.054	1.038	1.029
3	1.206	1.206	1.144	1.112	53	0.821	0.713	0.833	0.873
4	1.077	1.077	1.072	1.083	54	0.928	0.860	0.949	0.980
5	0.950	0.950	0.952	0.953	55	1.139	1.231	1.250	1.233
6	0.997	1.099	1.093	1.092	56	0.933	0.963	0.952	0.988
7	0.950	0.975	1.010	1.020	57	0.708	0.686	0.793	0.853
8	0.842	0.850	0.959	0.986	58	0.712	0.636	0.762	0.813
9	0.904	0.901	0.995	1.032	59	0.960	0.933	0.973	0.985
10	0.955	0.947	1.000	1.020	60	0.971	0.986	1.006	1.014
11	1.000	1.020	1.000	0.988	61	0.889	0.897	0.980	1.000
12	1.022	1.087	1.062	1.045	62	0.751	0.690	0.739	0.771
13	0.878	0.869	0.963	0.988	63	0.988	1.018	1.011	1.014
14	0.814	0.813	0.858	0.902	64	0.918	0.896	0.957	0.974
15	1.042	1.059	1.070	1.055	65	1.033	0.947	0.983	1.002
16	1.010	1.014	1.066	1.090	66	0.700	0.624	0.753	0.820
17	0.858	0.865	0.946	0.963	67	1.112	1.169	1.117	1.101
18	1.167	1.166	1.051	0.994	68	0.976	0.859	0.931	0.951
19	1.023	1.171	1.109	1.079	69	0.883	0.776	0.844	0.864
20	1.065	1.060	1.043	1.041	70	0.935	0.957	0.975	0.968
21	0.872	0.856	0.929	0.950	71	0.854	0.780	0.871	0.898
22	0.926	0.926	0.973	0.991	72	0.774	0.743	0.871	0.902
23	0.901	0.905	1.031	1.059	73	0.993	1.042	1.054	1.055
24	0.771	0.761	0.891	0.939	74	0.906	0.840	0.890	0.914
25	0.933	0.957	0.950	0.935	75	0.995	1.002	1.034	1.024
26	0.990	0.983	1.076	1.099	76	0.999	1.035	1.128	1.114
27	0.938	0.931	0.972	0.989	77	0.965	0.963	0.974	0.976
28	1.062	1.143	1.147	1.125	78	1.152	1.084	1.123	1.175
29	0.890	0.925	0.965	0.984	79	0.822	0.810	0.900	0.960
30	0.930	0.964	1.001	1.011	80	0.854	0.717	0.840	0.898
31	0.925	0.934	0.981	1.012	81	0.918	0.834	0.928	0.966
32	0.712	0.686	0.765	0.824	82	0.968	0.945	1.031	1.066
33	0.892	0.870	0.930	0.951	83	1.035	0.899	0.933	0.945
34	0.861	0.850	0.928	0.959	84	0.902	0.888	0.916	0.931
35	0.963	1.005	0.951	0.937	85	0.978	1.006	1.125	1.154
36	0.947	0.921	0.955	0.968	86	1.070	1.215	1.183	1.107
37	1.128	1.242	1.211	1.169	87	0.880	0.789	0.858	0.885
38	0.994	1.014	1.033	1.038	88	0.848	0.815	0.871	0.897
39	1.043	1.022	1.115	1.120	89	0.930	0.879	0.956	0.989
40	0.882	0.860	0.942	0.972	90	0.918	0.912	0.950	0.955
41	0.978	1.059	0.996	0.981	91	0.977	0.914	0.927	0.930
42	0.750	0.770	0.823	0.835	92	0.942	0.989	0.980	0.963
43	0.937	0.966	1.000	1.014	93	0.894	0.863	0.911	0.925
44	1.144	1.284	1.231	1.208	94	0.635	0.628	0.661	0.662
45	0.891	0.915	0.965	0.996	95	0.803	0.753	0.795	0.818
46	0.979	1.045	1.106	1.116	96	0.854	0.880	0.857	0.822
47	1.042	1.125	1.140	1.124	97	0.961	0.967	0.957	0.967
48	0.974	0.965	1.055	1.102	98	0.971	1.009	0.982	0.972
49	0.893	0.862	0.926	0.949	99	0.971	1.036	1.042	1.027
50	0.973	1.018	1.059	1.075	100	0.904	0.825	0.847	0.862

NC : Not Considered

Table A.4.9 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Base Shear for Frame 'F2S2B2'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	1.121	1.121	1.167	1.185	51	0.897	0.887	0.968	0.995
2	1.119	1.119	1.176	1.206	52	0.978	1.031	1.018	1.009
3	1.053	1.053	0.999	0.973	53	0.881	0.792	0.890	0.921
4	1.025	1.025	1.020	1.031	54	0.984	0.950	0.992	1.003
5	0.975	0.975	0.977	0.978	55	1.101	1.165	1.177	1.166
6	1.064	1.170	1.163	1.163	56	0.930	0.958	0.948	0.982
7	0.902	0.925	0.956	0.966	57	0.791	0.766	0.882	0.947
8	0.896	0.903	1.016	1.043	58	0.817	0.737	0.862	0.905
9	0.884	0.881	0.970	1.005	59	0.955	0.932	0.965	0.975
10	0.980	0.972	1.024	1.044	60	1.058	1.075	1.095	1.103
11	0.909	0.927	0.910	0.899	61	0.932	0.940	1.023	1.043
12	0.973	1.033	1.010	0.994	62	0.870	0.843	0.865	0.878
13	0.916	0.907	1.002	1.028	63	1.041	1.064	1.059	1.061
14	0.801	0.800	0.842	0.884	64	0.892	0.875	0.920	0.933
15	1.163	1.182	1.194	1.178	65	1.015	0.993	1.004	1.009
16	0.877	0.881	0.924	0.945	66	0.878	0.820	0.903	0.932
17	0.874	0.881	0.961	0.978	67	1.065	1.103	1.068	1.057
18	1.302	1.301	1.177	1.115	68	1.051	1.003	1.033	1.041
19	1.022	1.164	1.105	1.075	69	0.971	0.922	0.955	0.964
20	0.987	0.983	0.967	0.966	70	1.030	1.039	1.046	1.043
21	0.920	0.906	0.968	0.984	71	0.899	0.842	0.912	0.932
22	0.933	0.933	0.979	0.996	72	0.820	0.788	0.918	0.950
23	0.974	0.978	1.108	1.137	73	0.970	0.987	0.991	0.992
24	0.757	0.748	0.871	0.917	74	0.950	0.925	0.944	0.953
25	0.979	1.003	0.996	0.981	75	1.115	1.118	1.131	1.127
26	0.996	0.990	1.080	1.103	76	0.982	1.006	1.055	1.049
27	0.940	0.933	0.972	0.988	77	0.907	0.905	0.913	0.914
28	1.072	1.152	1.155	1.134	78	1.039	1.025	1.033	1.044
29	0.893	0.928	0.966	0.985	79	0.916	0.906	0.978	1.023
30	0.986	1.022	1.059	1.069	80	0.889	0.827	0.884	0.905
31	0.919	0.927	0.972	1.002	81	0.951	0.918	0.955	0.967
32	0.774	0.747	0.829	0.891	82	0.899	0.885	0.937	0.954
33	0.953	0.931	0.992	1.012	83	1.024	0.995	1.002	1.004
34	0.901	0.889	0.967	0.999	84	1.009	1.007	1.013	1.016
35	1.002	1.044	0.990	0.976	85	0.959	0.965	0.987	0.993
36	0.965	0.946	0.971	0.980	86	1.053	1.113	1.103	1.072
37	1.098	1.205	1.175	1.137	87	0.824	0.761	0.809	0.827
38	1.009	1.024	1.038	1.042	88	0.912	0.887	0.927	0.942
39	1.126	1.115	1.157	1.159	89	0.940	0.929	0.947	0.955
40	0.873	0.852	0.929	0.957	90	0.978	0.977	0.984	0.984
41	0.991	1.070	1.009	0.995	91	0.946	0.916	0.923	0.924
42	0.805	0.826	0.880	0.893	92	1.059	1.070	1.068	1.065
43	0.927	0.954	0.986	1.000	93	0.968	0.961	0.971	0.973
44	1.123	1.220	1.184	1.168	94	0.889	0.887	0.898	0.898
45	0.892	0.915	0.963	0.993	95	0.972	0.958	0.970	0.974
46	1.021	1.070	1.116	1.122	96	0.943	0.950	0.944	0.935
47	1.172	1.241	1.252	1.240	97	0.954	0.955	0.953	0.955
48	1.051	1.044	1.107	1.133	98	1.029	1.038	1.032	1.029
49	0.917	0.893	0.941	0.957	99	1.047	1.062	1.064	1.060
50	0.954	0.997	1.036	1.051	100	0.955	0.965	0.958	0.956

NC : Not Considered

Table A.4.10 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Top Displacement for Frame 'F2S2B2'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	1.046	1.065	51	0.989	1.083	1.114
2	1.000	1.061	1.093	52	1.058	1.043	1.033
3	1.000	0.946	0.920	53	0.869	1.016	1.066
4	1.000	0.995	1.006	54	0.920	1.025	1.062
5	1.000	1.002	1.003	55	1.085	1.102	1.086
6	1.103	1.097	1.096	56	1.032	1.021	1.058
7	1.026	1.063	1.074	57	0.968	1.120	1.206
8	1.009	1.141	1.172	58	0.894	1.070	1.142
9	0.996	1.101	1.142	59	0.972	1.014	1.027
10	0.991	1.047	1.068	60	1.016	1.036	1.045
11	1.020	1.000	0.988	61	1.009	1.102	1.125
12	1.064	1.040	1.022	62	0.912	0.983	1.030
13	0.990	1.097	1.126	63	1.030	1.023	1.026
14	0.998	1.054	1.108	64	0.976	1.042	1.061
15	1.017	1.027	1.013	65	0.902	0.941	0.963
16	1.004	1.056	1.080	66	0.882	1.083	1.189
17	1.008	1.103	1.123	67	1.055	1.004	0.989
18	0.999	0.900	0.851	68	0.869	0.949	0.971
19	1.145	1.085	1.054	69	0.867	0.950	0.976
20	0.995	0.978	0.977	70	1.026	1.047	1.039
21	0.982	1.064	1.088	71	0.911	1.020	1.054
22	1.000	1.051	1.070	72	0.959	1.124	1.165
23	1.004	1.144	1.176	73	1.055	1.068	1.070
24	0.987	1.156	1.219	74	0.921	0.980	1.010
25	1.026	1.018	1.002	75	1.008	1.043	1.032
26	0.993	1.088	1.111	76	1.038	1.142	1.126
27	0.992	1.035	1.054	77	0.998	1.010	1.012
28	1.077	1.080	1.060	78	0.930	0.971	1.024
29	1.040	1.085	1.107	79	0.985	1.098	1.175
30	1.037	1.076	1.087	80	0.826	0.982	1.056
31	1.010	1.060	1.094	81	0.900	1.013	1.060
32	0.963	1.074	1.157	82	0.976	1.071	1.111
33	0.976	1.042	1.066	83	0.843	0.882	0.896
34	0.987	1.077	1.114	84	0.980	1.019	1.040
35	1.044	0.988	0.973	85	1.037	1.186	1.223
36	0.972	1.009	1.023	86	1.149	1.115	1.038
37	1.102	1.073	1.037	87	0.894	0.975	1.006
38	1.022	1.041	1.046	88	0.959	1.030	1.063
39	0.978	1.075	1.081	89	0.936	1.033	1.074
40	0.975	1.068	1.102	90	0.992	1.043	1.050
41	1.084	1.019	1.004	91	0.930	0.944	0.948
42	1.027	1.097	1.114	92	1.061	1.050	1.028
43	1.031	1.067	1.082	93	0.958	1.024	1.044
44	1.127	1.078	1.058	94	0.987	1.047	1.050
45	1.027	1.083	1.118	95	0.926	0.988	1.024
46	1.070	1.135	1.146	96	1.035	1.004	0.956
47	1.081	1.096	1.080	97	1.008	0.996	1.007
48	0.990	1.091	1.144	98	1.047	1.013	1.001
49	0.963	1.037	1.064	99	1.079	1.087	1.068
50	1.047	1.090	1.106	100	0.914	0.936	0.953

NC : Not Considered

Table A.4.11 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Inter-story Drift Ratio for Frame 'F2S2B2'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	1.045	1.064	51	0.989	1.082	1.114
2	1.000	1.058	1.089	52	1.058	1.043	1.033
3	1.000	0.948	0.923	53	0.869	1.015	1.064
4	1.000	0.995	1.006	54	0.926	1.022	1.056
5	1.000	1.002	1.003	55	1.081	1.097	1.083
6	1.103	1.096	1.096	56	1.032	1.021	1.058
7	1.026	1.062	1.073	57	0.968	1.120	1.205
8	1.009	1.140	1.171	58	0.894	1.071	1.142
9	0.996	1.101	1.141	59	0.972	1.014	1.027
10	0.991	1.046	1.067	60	1.016	1.036	1.044
11	1.020	1.000	0.989	61	1.009	1.102	1.125
12	1.064	1.039	1.022	62	0.919	0.984	1.027
13	0.990	1.097	1.126	63	1.030	1.023	1.026
14	0.998	1.054	1.107	64	0.976	1.042	1.062
15	1.017	1.027	1.013	65	0.917	0.952	0.970
16	1.004	1.055	1.080	66	0.892	1.076	1.171
17	1.008	1.103	1.123	67	1.052	1.004	0.990
18	0.999	0.900	0.852	68	0.880	0.953	0.974
19	1.144	1.084	1.054	69	0.878	0.955	0.978
20	0.995	0.979	0.977	70	1.023	1.042	1.035
21	0.982	1.065	1.089	71	0.913	1.020	1.052
22	1.000	1.051	1.070	72	0.959	1.124	1.165
23	1.004	1.144	1.175	73	1.050	1.061	1.063
24	0.987	1.155	1.218	74	0.928	0.982	1.009
25	1.026	1.018	1.002	75	1.007	1.039	1.029
26	0.993	1.087	1.111	76	1.036	1.129	1.115
27	0.992	1.035	1.054	77	0.998	1.010	1.011
28	1.077	1.080	1.060	78	0.941	0.975	1.020
29	1.040	1.084	1.106	79	0.986	1.094	1.167
30	1.037	1.076	1.087	80	0.840	0.984	1.051
31	1.010	1.060	1.093	81	0.909	1.012	1.053
32	0.963	1.074	1.156	82	0.977	1.065	1.101
33	0.976	1.042	1.066	83	0.869	0.902	0.913
34	0.987	1.077	1.113	84	0.984	1.016	1.033
35	1.043	0.988	0.973	85	1.030	1.151	1.181
36	0.973	1.009	1.022	86	1.135	1.105	1.034
37	1.101	1.073	1.036	87	0.897	0.975	1.006
38	1.021	1.040	1.045	88	0.961	1.026	1.057
39	0.980	1.069	1.074	89	0.945	1.028	1.064
40	0.975	1.068	1.101	90	0.994	1.035	1.040
41	1.083	1.019	1.004	91	0.935	0.948	0.951
42	1.027	1.097	1.113	92	1.050	1.041	1.023
43	1.031	1.067	1.082	93	0.966	1.019	1.035
44	1.122	1.076	1.056	94	0.989	1.040	1.043
45	1.027	1.083	1.117	95	0.938	0.990	1.019
46	1.067	1.130	1.140	96	1.030	1.003	0.962
47	1.080	1.095	1.080	97	1.007	0.996	1.006
48	0.990	1.083	1.131	98	1.039	1.011	1.001
49	0.964	1.036	1.062	99	1.067	1.073	1.057
50	1.047	1.089	1.105	100	0.912	0.937	0.954

NC : Not Considered

Table A.4.12 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Base Shear for Frame 'F2S2B2'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	1.041	1.058	51	0.989	1.079	1.110
2	1.000	1.051	1.077	52	1.055	1.041	1.032
3	1.000	0.949	0.925	53	0.899	1.011	1.046
4	1.000	0.995	1.006	54	0.965	1.008	1.020
5	1.000	1.002	1.003	55	1.058	1.069	1.059
6	1.099	1.093	1.093	56	1.031	1.020	1.056
7	1.025	1.060	1.071	57	0.969	1.116	1.197
8	1.009	1.135	1.165	58	0.902	1.056	1.108
9	0.996	1.097	1.137	59	0.976	1.011	1.021
10	0.991	1.045	1.065	60	1.016	1.035	1.043
11	1.019	1.000	0.989	61	1.009	1.098	1.119
12	1.062	1.038	1.022	62	0.969	0.994	1.010
13	0.990	1.094	1.122	63	1.022	1.017	1.019
14	0.998	1.052	1.104	64	0.981	1.032	1.046
15	1.016	1.026	1.013	65	0.978	0.989	0.994
16	1.004	1.053	1.077	66	0.933	1.029	1.061
17	1.008	1.099	1.119	67	1.036	1.003	0.993
18	0.999	0.904	0.856	68	0.955	0.983	0.991
19	1.139	1.081	1.052	69	0.949	0.984	0.992
20	0.995	0.979	0.978	70	1.008	1.015	1.013
21	0.985	1.051	1.069	71	0.936	1.014	1.037
22	1.000	1.050	1.067	72	0.960	1.119	1.158
23	1.004	1.138	1.168	73	1.018	1.022	1.022
24	0.987	1.150	1.211	74	0.973	0.993	1.003
25	1.025	1.018	1.002	75	1.003	1.014	1.010
26	0.993	1.084	1.107	76	1.025	1.075	1.068
27	0.992	1.034	1.051	77	0.999	1.007	1.008
28	1.074	1.077	1.057	78	0.986	0.994	1.005
29	1.039	1.082	1.103	79	0.990	1.067	1.117
30	1.036	1.073	1.084	80	0.930	0.994	1.018
31	1.009	1.058	1.090	81	0.966	1.004	1.017
32	0.964	1.071	1.150	82	0.983	1.042	1.061
33	0.977	1.041	1.061	83	0.972	0.979	0.981
34	0.987	1.074	1.109	84	0.998	1.003	1.007
35	1.042	0.988	0.974	85	1.006	1.029	1.035
36	0.981	1.006	1.016	86	1.057	1.047	1.018
37	1.098	1.070	1.035	87	0.924	0.982	1.004
38	1.015	1.028	1.032	88	0.973	1.016	1.033
39	0.990	1.027	1.029	89	0.988	1.007	1.016
40	0.976	1.065	1.097	90	0.999	1.006	1.006
41	1.080	1.018	1.004	91	0.968	0.975	0.977
42	1.026	1.093	1.109	92	1.010	1.008	1.005
43	1.030	1.065	1.079	93	0.993	1.003	1.005
44	1.087	1.054	1.040	94	0.997	1.010	1.010
45	1.026	1.080	1.113	95	0.986	0.998	1.002
46	1.048	1.093	1.099	96	1.007	1.001	0.991
47	1.059	1.069	1.058	97	1.002	0.999	1.002
48	0.993	1.053	1.077	98	1.009	1.003	1.000
49	0.974	1.026	1.044	99	1.015	1.016	1.012
50	1.045	1.086	1.101	100	1.010	1.003	1.001

NC : Not Considered

Table A.4.13 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Top Displacement for Frame 'F3S2B'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	1.570	1.570	1.618	1.555	51	1.099	1.213	1.157	1.110
2	1.093	1.093	1.157	1.193	52	0.830	0.713	0.777	0.799
3	1.034	1.034	1.189	1.296	53	1.072	1.147	1.123	1.095
4	1.110	1.110	1.114	1.108	54	0.976	1.053	1.051	1.015
5	0.973	0.973	1.028	1.055	55	0.836	1.024	1.094	1.064
6	1.178	1.189	0.988	0.860	56	0.924	0.909	0.967	1.013
7	0.972	1.020	1.015	1.028	57	0.934	0.951	1.018	1.041
8	1.135	1.223	1.081	0.997	58	0.831	0.882	0.994	0.991
9	0.934	1.087	1.021	1.027	59	0.906	0.806	0.863	0.911
10	0.991	1.014	1.059	1.039	60	0.916	0.912	0.929	0.961
11	1.143	1.166	1.094	0.978	61	0.987	1.030	1.119	1.113
12	0.985	1.043	0.960	1.039	62	0.967	1.087	1.242	1.311
13	0.804	0.752	0.862	0.954	63	1.035	1.102	1.110	1.083
14	1.136	1.279	1.262	1.179	64	0.828	0.831	0.851	0.927
15	1.091	1.125	1.109	1.115	65	1.043	1.186	1.152	1.120
16	0.933	0.990	1.012	1.020	66	0.743	0.656	0.672	0.716
17	0.785	0.782	0.890	0.989	67	0.852	0.843	0.893	0.923
18	0.835	0.853	0.962	1.043	68	0.808	0.695	0.741	0.793
19	0.846	0.840	0.909	0.970	69	0.926	0.940	1.003	1.029
20	0.971	0.971	0.985	1.019	70	0.970	1.010	1.084	1.088
21	0.981	1.202	1.146	1.143	71	0.871	0.848	0.947	0.954
22	0.865	0.875	0.913	0.997	72	0.870	0.797	0.891	0.953
23	0.940	0.921	0.974	1.052	73	0.835	0.741	0.831	0.901
24	1.048	1.115	1.049	1.006	74	0.895	0.715	0.763	0.813
25	0.691	0.729	0.768	0.806	75	0.959	0.995	1.028	1.052
26	0.962	1.011	1.029	1.027	76	1.058	1.384	1.218	1.125
27	0.800	0.777	0.858	0.958	77	0.856	0.762	0.726	0.779
28	0.916	0.884	0.933	0.965	78	1.036	1.129	1.162	1.173
29	0.926	0.915	0.970	0.996	79	0.880	0.725	0.803	0.859
30	1.009	1.021	1.000	0.981	80	1.035	0.995	1.000	1.014
31	0.938	0.935	0.971	1.006	81	0.844	0.779	0.820	0.854
32	0.960	0.885	1.005	1.018	82	0.728	0.782	0.702	0.685
33	0.992	1.008	1.018	1.017	83	0.842	0.762	0.776	0.789
34	0.873	0.910	0.937	0.999	84	0.967	0.940	0.976	1.005
35	1.085	1.186	1.287	1.226	85	1.059	0.931	1.004	1.040
36	0.955	1.098	1.178	1.186	86	1.090	1.180	1.244	1.262
37	0.757	0.721	0.791	0.827	87	0.882	0.793	0.836	0.879
38	0.865	0.943	0.982	0.969	88	0.951	0.894	0.957	1.000
39	0.808	0.856	0.825	0.905	89	0.939	0.833	0.922	0.985
40	0.885	0.873	0.968	1.006	90	0.945	0.900	0.954	0.989
41	0.868	0.859	0.964	1.081	91	0.874	0.838	0.885	0.912
42	0.892	0.914	0.963	0.970	92	0.969	1.059	1.160	1.209
43	0.833	0.756	0.845	0.901	93	1.104	1.190	1.105	1.046
44	0.875	0.893	0.943	1.018	94	0.699	0.665	0.660	0.656
45	0.690	0.653	0.734	0.798	95	0.908	0.825	0.869	0.910
46	0.909	0.914	0.938	0.972	96	1.167	1.229	1.314	1.366
47	0.778	0.831	0.836	0.931	97	0.909	0.861	0.907	0.988
48	0.840	0.743	0.881	0.964	98	0.983	0.959	1.038	1.094
49	0.946	0.935	1.031	1.078	99	1.003	0.950	0.987	1.023
50	0.870	0.799	0.873	0.920	100	0.985	0.898	0.918	0.936

NC : Not Considered

Table A.4.14 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Inter-story Drift Ratio for Frame 'F3S2B'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	1.563	1.563	1.610	1.547	51	1.094	1.195	1.146	1.103
2	1.085	1.085	1.149	1.183	52	0.859	0.751	0.811	0.831
3	1.028	1.029	1.187	1.296	53	1.069	1.145	1.121	1.092
4	1.101	1.101	1.104	1.098	54	0.987	1.056	1.054	1.022
5	0.974	0.974	1.031	1.059	55	0.839	1.027	1.093	1.066
6	1.185	1.195	0.991	0.861	56	0.940	0.927	0.978	1.018
7	0.965	1.013	1.008	1.022	57	0.933	0.950	1.018	1.041
8	1.135	1.224	1.081	0.995	58	0.858	0.902	0.998	0.996
9	0.933	1.086	1.020	1.025	59	0.916	0.816	0.874	0.921
10	0.989	1.012	1.058	1.038	60	0.911	0.907	0.924	0.957
11	1.130	1.153	1.080	0.965	61	0.998	1.041	1.133	1.126
12	0.980	1.038	0.955	1.035	62	0.975	1.082	1.217	1.274
13	0.804	0.752	0.862	0.954	63	1.039	1.100	1.106	1.082
14	1.139	1.283	1.265	1.182	64	0.831	0.834	0.854	0.930
15	1.085	1.119	1.103	1.109	65	1.034	1.159	1.129	1.102
16	0.934	0.991	1.013	1.021	66	0.789	0.708	0.723	0.764
17	0.784	0.780	0.889	0.989	67	0.878	0.869	0.916	0.942
18	0.832	0.849	0.958	1.040	68	0.835	0.729	0.773	0.821
19	0.845	0.838	0.908	0.970	69	0.952	0.964	1.020	1.042
20	0.971	0.971	0.985	1.019	70	0.988	1.024	1.088	1.091
21	0.981	1.200	1.145	1.143	71	0.880	0.858	0.949	0.956
22	0.865	0.875	0.913	0.998	72	0.872	0.799	0.894	0.955
23	0.937	0.917	0.970	1.049	73	0.859	0.773	0.855	0.917
24	1.046	1.114	1.047	1.004	74	0.904	0.746	0.789	0.833
25	0.689	0.727	0.766	0.804	75	0.972	1.004	1.033	1.053
26	0.973	1.017	1.033	1.031	76	1.054	1.344	1.200	1.117
27	0.800	0.776	0.859	0.959	77	0.866	0.770	0.733	0.788
28	0.917	0.885	0.934	0.967	78	1.034	1.117	1.147	1.157
29	0.925	0.913	0.969	0.996	79	0.899	0.762	0.832	0.880
30	0.989	1.002	0.980	0.962	80	1.036	0.999	1.003	1.017
31	0.933	0.930	0.967	1.002	81	0.861	0.803	0.840	0.871
32	0.962	0.888	1.006	1.018	82	0.760	0.811	0.736	0.720
33	0.988	1.004	1.014	1.014	83	0.858	0.782	0.795	0.808
34	0.869	0.905	0.933	0.994	84	0.969	0.945	0.977	1.001
35	1.087	1.190	1.293	1.231	85	1.095	0.976	1.043	1.078
36	0.956	1.096	1.170	1.176	86	1.074	1.153	1.209	1.224
37	0.756	0.719	0.790	0.827	87	0.894	0.814	0.853	0.891
38	0.863	0.942	0.982	0.969	88	0.955	0.902	0.960	0.998
39	0.802	0.850	0.819	0.900	89	0.944	0.847	0.929	0.986
40	0.901	0.889	0.978	1.013	90	0.956	0.916	0.964	0.995
41	0.877	0.868	0.967	1.071	91	0.891	0.857	0.901	0.926
42	0.903	0.922	0.966	0.972	92	0.974	1.051	1.139	1.181
43	0.851	0.773	0.863	0.916	93	1.111	1.190	1.112	1.058
44	0.875	0.894	0.945	1.020	94	0.717	0.684	0.680	0.676
45	0.692	0.654	0.736	0.801	95	0.962	0.886	0.926	0.964
46	0.910	0.916	0.940	0.974	96	1.122	1.176	1.250	1.295
47	0.779	0.833	0.838	0.934	97	0.915	0.871	0.913	0.987
48	0.862	0.764	0.901	0.977	98	0.977	0.955	1.025	1.076
49	0.953	0.943	1.032	1.073	99	1.007	0.957	0.992	1.025
50	0.880	0.808	0.882	0.930	100	0.967	0.885	0.905	0.921

NC : Not Considered

Table A.4.15 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Base Shear for Frame 'F3S2B'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	1.331	1.331	1.365	1.321	51	1.034	1.073	1.055	1.038
2	1.104	1.104	1.158	1.187	52	0.904	0.856	0.884	0.893
3	1.003	1.003	1.143	1.239	53	1.151	1.204	1.187	1.168
4	1.012	1.012	1.015	1.010	54	0.899	0.924	0.924	0.913
5	1.039	1.039	1.097	1.124	55	0.826	0.940	0.973	0.960
6	1.112	1.121	0.940	0.825	56	0.894	0.891	0.905	0.917
7	0.887	0.928	0.924	0.935	57	0.989	1.001	1.046	1.061
8	1.105	1.187	1.055	0.975	58	0.927	0.941	0.965	0.965
9	0.912	1.055	0.993	0.998	59	0.850	0.789	0.825	0.853
10	1.006	1.029	1.073	1.054	60	0.928	0.924	0.941	0.972
11	1.068	1.088	1.023	0.920	61	0.999	1.028	1.085	1.081
12	0.918	0.969	0.895	0.966	62	0.943	0.986	1.030	1.045
13	0.806	0.756	0.861	0.949	63	0.974	0.998	1.001	0.991
14	1.087	1.174	1.163	1.113	64	0.836	0.838	0.851	0.899
15	1.011	1.041	1.027	1.032	65	1.208	1.266	1.254	1.241
16	0.917	0.971	0.992	0.999	66	0.901	0.868	0.875	0.892
17	0.810	0.807	0.913	0.992	67	0.895	0.891	0.910	0.920
18	0.763	0.778	0.873	0.944	68	0.903	0.849	0.874	0.897
19	0.868	0.863	0.912	0.952	69	0.893	0.897	0.913	0.918
20	0.946	0.947	0.958	0.987	70	0.860	0.871	0.888	0.889
21	0.956	1.088	1.057	1.055	71	0.927	0.915	0.962	0.965
22	0.865	0.872	0.897	0.951	72	0.845	0.799	0.859	0.897
23	0.892	0.874	0.922	0.993	73	0.931	0.893	0.929	0.951
24	1.070	1.136	1.071	1.029	74	0.977	0.926	0.943	0.957
25	0.702	0.739	0.776	0.813	75	0.892	0.901	0.908	0.914
26	0.969	0.987	0.994	0.993	76	1.072	1.194	1.140	1.104
27	0.957	0.938	1.002	1.075	77	0.789	0.732	0.709	0.742
28	0.874	0.845	0.890	0.919	78	0.937	0.957	0.960	0.961
29	0.901	0.894	0.929	0.946	79	0.927	0.885	0.910	0.922
30	1.111	1.124	1.101	1.081	80	0.835	0.836	0.836	0.835
31	0.915	0.912	0.946	0.977	81	0.867	0.849	0.861	0.870
32	0.958	0.911	0.983	0.989	82	0.984	0.992	0.976	0.968
33	1.119	1.130	1.137	1.137	83	0.871	0.876	0.874	0.874
34	0.828	0.861	0.886	0.941	84	0.996	0.987	0.999	1.007
35	1.016	1.077	1.136	1.101	85	0.989	0.954	0.976	0.986
36	1.060	1.152	1.190	1.194	86	0.981	1.012	1.032	1.038
37	0.785	0.753	0.809	0.833	87	0.901	0.876	0.888	0.900
38	0.919	0.974	1.001	0.992	88	0.949	0.947	0.948	0.942
39	1.054	1.104	1.074	1.146	89	0.952	0.924	0.950	0.957
40	0.879	0.872	0.917	0.931	90	0.903	0.891	0.906	0.914
41	0.924	0.919	0.972	1.015	91	0.916	0.913	0.917	0.918
42	0.968	0.977	0.996	0.999	92	1.017	1.038	1.064	1.076
43	0.859	0.808	0.865	0.894	93	0.886	0.894	0.886	0.873
44	0.878	0.891	0.923	0.969	94	0.816	0.818	0.818	0.819
45	0.758	0.719	0.797	0.842	95	0.899	0.878	0.889	0.899
46	0.968	0.972	0.988	1.011	96	0.961	0.972	0.979	0.980
47	0.829	0.884	0.889	0.978	97	1.001	0.988	1.001	1.010
48	0.903	0.840	0.924	0.959	98	0.969	0.968	0.964	0.959
49	0.983	0.978	1.022	1.040	99	0.841	0.841	0.841	0.837
50	0.832	0.788	0.833	0.863	100	0.860	0.869	0.868	0.866

NC : Not Considered

Table A.4.16 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Top Displacement for Frame 'F3S2B'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	1.031	0.990	51	1.104	1.053	1.010
2	1.000	1.059	1.091	52	0.860	0.937	0.963
3	1.000	1.150	1.253	53	1.070	1.047	1.021
4	1.000	1.003	0.998	54	1.079	1.077	1.040
5	1.000	1.057	1.084	55	1.225	1.308	1.273
6	1.009	0.839	0.730	56	0.984	1.047	1.096
7	1.049	1.044	1.058	57	1.018	1.090	1.115
8	1.077	0.953	0.878	58	1.061	1.196	1.192
9	1.164	1.093	1.099	59	0.890	0.953	1.005
10	1.023	1.070	1.049	60	0.996	1.015	1.050
11	1.020	0.956	0.856	61	1.043	1.134	1.127
12	1.059	0.974	1.055	62	1.124	1.284	1.356
13	0.935	1.071	1.186	63	1.065	1.072	1.046
14	1.126	1.110	1.037	64	1.004	1.028	1.120
15	1.030	1.016	1.022	65	1.137	1.104	1.074
16	1.061	1.084	1.093	66	0.883	0.904	0.963
17	0.996	1.133	1.260	67	0.989	1.048	1.083
18	1.021	1.151	1.248	68	0.861	0.918	0.982
19	0.992	1.074	1.146	69	1.015	1.083	1.111
20	1.000	1.014	1.049	70	1.041	1.118	1.122
21	1.225	1.168	1.165	71	0.973	1.086	1.095
22	1.012	1.055	1.152	72	0.917	1.025	1.096
23	0.979	1.036	1.118	73	0.887	0.995	1.079
24	1.064	1.001	0.960	74	0.799	0.852	0.908
25	1.055	1.111	1.166	75	1.037	1.072	1.096
26	1.052	1.070	1.067	76	1.308	1.152	1.063
27	0.971	1.073	1.197	77	0.890	0.848	0.910
28	0.966	1.018	1.054	78	1.089	1.122	1.132
29	0.988	1.047	1.076	79	0.824	0.912	0.975
30	1.012	0.991	0.972	80	0.962	0.966	0.980
31	0.997	1.036	1.073	81	0.923	0.972	1.012
32	0.922	1.047	1.060	82	1.075	0.965	0.941
33	1.016	1.025	1.025	83	0.905	0.921	0.937
34	1.042	1.073	1.143	84	0.972	1.009	1.039
35	1.093	1.186	1.130	85	0.879	0.948	0.983
36	1.150	1.233	1.241	86	1.083	1.141	1.158
37	0.952	1.044	1.093	87	0.899	0.948	0.996
38	1.090	1.135	1.121	88	0.940	1.006	1.051
39	1.059	1.021	1.120	89	0.887	0.983	1.049
40	0.986	1.093	1.137	90	0.952	1.010	1.047
41	0.990	1.111	1.246	91	0.959	1.012	1.043
42	1.024	1.079	1.087	92	1.093	1.198	1.249
43	0.908	1.014	1.082	93	1.078	1.001	0.947
44	1.021	1.079	1.164	94	0.952	0.945	0.939
45	0.946	1.063	1.157	95	0.909	0.957	1.002
46	1.006	1.033	1.070	96	1.053	1.126	1.170
47	1.069	1.075	1.198	97	0.947	0.997	1.086
48	0.885	1.049	1.148	98	0.976	1.056	1.113
49	0.988	1.090	1.139	99	0.947	0.984	1.020
50	0.918	1.003	1.057	100	0.912	0.933	0.951

NC : Not Considered

Table A.4.17 Comparison Results of Approximations with respect to ‘MULTI’ Values of Maximum Inter-story Drift Ratio for Frame ‘F3S2B’

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	1.030	0.990	51	1.093	1.047	1.009
2	1.000	1.059	1.091	52	0.875	0.944	0.968
3	1.000	1.154	1.260	53	1.071	1.048	1.022
4	1.000	1.003	0.998	54	1.070	1.068	1.036
5	1.000	1.059	1.087	55	1.224	1.303	1.270
6	1.009	0.837	0.727	56	0.986	1.041	1.083
7	1.049	1.044	1.058	57	1.019	1.091	1.116
8	1.078	0.952	0.877	58	1.052	1.164	1.161
9	1.165	1.093	1.100	59	0.890	0.953	1.005
10	1.023	1.070	1.050	60	0.996	1.015	1.050
11	1.020	0.956	0.854	61	1.044	1.136	1.129
12	1.059	0.974	1.055	62	1.110	1.248	1.307
13	0.935	1.072	1.187	63	1.058	1.064	1.041
14	1.127	1.111	1.038	64	1.004	1.028	1.119
15	1.031	1.016	1.022	65	1.121	1.093	1.066
16	1.061	1.085	1.094	66	0.897	0.916	0.968
17	0.996	1.134	1.263	67	0.990	1.043	1.073
18	1.021	1.152	1.251	68	0.873	0.926	0.984
19	0.992	1.075	1.148	69	1.013	1.071	1.095
20	1.000	1.014	1.050	70	1.036	1.101	1.104
21	1.224	1.168	1.165	71	0.975	1.079	1.086
22	1.012	1.056	1.155	72	0.916	1.025	1.095
23	0.979	1.036	1.120	73	0.900	0.995	1.068
24	1.065	1.001	0.960	74	0.825	0.873	0.921
25	1.055	1.111	1.167	75	1.032	1.063	1.084
26	1.046	1.062	1.060	76	1.275	1.138	1.059
27	0.971	1.074	1.198	77	0.890	0.847	0.910
28	0.966	1.019	1.054	78	1.081	1.110	1.119
29	0.988	1.048	1.077	79	0.848	0.926	0.979
30	1.012	0.991	0.972	80	0.965	0.969	0.982
31	0.997	1.036	1.074	81	0.932	0.975	1.011
32	0.923	1.046	1.058	82	1.068	0.968	0.947
33	1.016	1.026	1.026	83	0.911	0.927	0.942
34	1.042	1.073	1.144	84	0.975	1.008	1.033
35	1.095	1.189	1.132	85	0.891	0.952	0.984
36	1.146	1.223	1.230	86	1.074	1.126	1.140
37	0.952	1.045	1.094	87	0.911	0.954	0.996
38	1.091	1.137	1.123	88	0.945	1.006	1.046
39	1.059	1.021	1.122	89	0.898	0.984	1.045
40	0.987	1.086	1.125	90	0.958	1.008	1.041
41	0.990	1.103	1.221	91	0.962	1.011	1.039
42	1.022	1.070	1.077	92	1.079	1.169	1.213
43	0.909	1.014	1.077	93	1.071	1.001	0.952
44	1.022	1.080	1.165	94	0.954	0.948	0.943
45	0.945	1.064	1.159	95	0.921	0.963	1.002
46	1.006	1.033	1.070	96	1.048	1.114	1.154
47	1.069	1.075	1.199	97	0.952	0.997	1.078
48	0.887	1.045	1.134	98	0.978	1.050	1.102
49	0.989	1.082	1.126	99	0.950	0.985	1.018
50	0.919	1.003	1.057	100	0.916	0.936	0.953

NC : Not Considered

Table A.4.18 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Base Shear for Frame 'F3S2B'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	1.026	0.992	51	1.038	1.020	1.004
2	1.000	1.049	1.075	52	0.948	0.978	0.988
3	1.000	1.140	1.236	53	1.045	1.031	1.014
4	1.000	1.003	0.998	54	1.028	1.027	1.015
5	1.000	1.056	1.082	55	1.137	1.177	1.162
6	1.008	0.846	0.742	56	0.996	1.012	1.025
7	1.047	1.042	1.055	57	1.012	1.058	1.073
8	1.074	0.954	0.883	58	1.016	1.042	1.041
9	1.157	1.089	1.095	59	0.928	0.970	1.003
10	1.022	1.067	1.047	60	0.996	1.014	1.048
11	1.019	0.958	0.862	61	1.028	1.086	1.082
12	1.056	0.975	1.052	62	1.045	1.092	1.107
13	0.938	1.068	1.177	63	1.025	1.028	1.018
14	1.079	1.070	1.024	64	1.003	1.018	1.076
15	1.029	1.015	1.021	65	1.048	1.038	1.027
16	1.058	1.081	1.089	66	0.963	0.971	0.990
17	0.996	1.127	1.224	67	0.996	1.017	1.028
18	1.020	1.144	1.237	68	0.940	0.968	0.993
19	0.993	1.050	1.097	69	1.004	1.022	1.029
20	1.000	1.012	1.042	70	1.013	1.033	1.034
21	1.138	1.105	1.104	71	0.986	1.037	1.040
22	1.008	1.037	1.099	72	0.946	1.016	1.061
23	0.980	1.034	1.113	73	0.959	0.998	1.021
24	1.061	1.001	0.962	74	0.947	0.965	0.979
25	1.053	1.106	1.158	75	1.010	1.019	1.025
26	1.019	1.026	1.025	76	1.115	1.064	1.031
27	0.981	1.048	1.124	77	0.928	0.899	0.941
28	0.967	1.018	1.052	78	1.021	1.024	1.025
29	0.992	1.031	1.049	79	0.954	0.982	0.994
30	1.012	0.992	0.974	80	1.001	1.001	1.001
31	0.997	1.034	1.067	81	0.979	0.993	1.003
32	0.951	1.026	1.033	82	1.008	0.992	0.984
33	1.010	1.016	1.016	83	1.005	1.003	1.003
34	1.040	1.070	1.137	84	0.991	1.003	1.011
35	1.061	1.119	1.084	85	0.965	0.986	0.997
36	1.087	1.123	1.126	86	1.032	1.053	1.058
37	0.959	1.030	1.062	87	0.972	0.986	0.999
38	1.060	1.089	1.080	88	0.998	0.999	0.993
39	1.047	1.019	1.087	89	0.970	0.997	1.005
40	0.992	1.044	1.060	90	0.986	1.002	1.012
41	0.994	1.051	1.098	91	0.996	1.001	1.001
42	1.009	1.029	1.032	92	1.021	1.046	1.058
43	0.942	1.008	1.041	93	1.009	1.000	0.986
44	1.014	1.051	1.104	94	1.003	1.004	1.004
45	0.949	1.051	1.111	95	0.977	0.989	1.001
46	1.004	1.021	1.044	96	1.012	1.019	1.020
47	1.066	1.072	1.180	97	0.987	1.000	1.008
48	0.930	1.023	1.061	98	0.999	0.994	0.989
49	0.994	1.040	1.057	99	1.000	0.999	0.995
50	0.947	1.002	1.037	100	1.010	1.009	1.007

NC : Not Considered

Table A.4.19 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Top Displacement for Frame 'F5S2B'

EQ	MULTI	ATC	FEMA	75%Vy
1	1.016	1.016	1.632	1.839
2	1.027	1.026	1.601	1.741
3	1.020	1.008	1.211	1.245
4	0.987	0.988	0.927	0.929
5	0.982	0.987	1.135	1.110
6	0.933	0.933	0.860	0.909
7	0.787	0.852	1.065	1.049
8	0.649	0.685	1.222	1.269
9	0.994	1.200	0.936	0.889
10	0.960	1.326	1.004	1.089
11	0.907	1.012	0.915	0.928
12	0.744	0.747	1.013	1.011
13	0.735	0.693	0.943	1.009
14	0.823	0.646	0.951	1.027
15	0.936	0.972	1.349	1.288
16	0.951	0.922	0.979	0.987
17	0.636	0.569	1.003	1.095
18	0.818	1.180	0.865	0.873
19	0.771	0.655	0.943	1.038
20	0.911	0.522	0.847	0.896
21	0.925	1.031	1.020	1.036
22	0.915	0.944	1.002	1.018
23	0.874	1.010	1.098	1.040
24	0.813	1.024	1.386	1.478
25	0.722	0.694	0.992	1.108
26	0.894	0.846	1.108	1.134
27	0.951	1.027	0.990	0.991
28	0.807	0.522	0.782	0.825
29	0.874	0.805	0.879	0.955
30	0.922	1.037	0.732	0.727
31	1.091	1.425	1.143	1.071
32	1.031	1.176	0.988	1.023
33	0.938	1.014	0.923	0.907
34	0.996	0.886	1.198	1.315
35	0.793	0.677	0.994	1.015
36	0.966	1.246	1.028	1.002
37	0.935	0.994	1.081	0.995
38	0.884	0.893	0.995	1.041
39	0.856	0.985	0.873	0.855
40	0.935	0.743	1.009	1.034
41	0.960	0.862	1.220	1.242
42	0.929	1.175	1.035	1.012
43	1.031	0.857	1.134	1.090
44	0.755	0.702	0.882	0.926
45	0.846	0.919	1.023	1.040
46	0.964	1.008	0.946	0.953
47	0.815	0.560	1.022	1.103
48	0.883	0.694	0.970	1.006
49	0.888	0.759	0.979	1.018
50	1.038	1.013	0.985	0.959
51	0.950	0.851	1.081	1.089
52	1.032	0.999	1.044	1.067
53	0.852	0.816	0.989	1.042
54	NC	NC	NC	NC
55	0.895	0.818	1.036	0.979
56	0.828	0.725	0.751	0.762
57	0.682	0.853	0.975	1.082
58	1.207	0.850	1.350	1.189
59	1.056	0.911	1.115	1.138
60	0.883	0.832	1.123	1.127
61	0.814	0.670	1.051	1.045
62	1.035	1.356	1.148	1.111
63	1.047	1.165	1.448	1.447
64	1.075	0.976	1.051	1.039
65	0.819	0.612	0.950	0.989
66	1.077	1.195	1.187	1.274
67	1.076	1.107	1.192	1.220
68	0.892	0.945	1.054	1.052
69	1.226	1.379	1.454	1.434
70	0.962	0.757	0.962	0.983
71	0.945	1.347	1.015	0.996
72	0.919	0.813	0.998	1.014
73	0.908	0.748	0.974	1.010
74	1.092	1.321	1.504	1.459
75	1.105	1.381	1.255	1.247
76	0.947	0.776	1.027	1.056
77	0.609	0.652	0.463	0.506
78	1.257	1.406	1.454	1.430
79	0.972	1.046	1.079	1.090
80	0.735	0.708	0.661	0.663
81	NC	NC	NC	NC
82	1.028	0.803	1.097	1.079
83	1.064	1.190	1.176	1.167
84	0.986	0.959	1.008	1.007
85	1.361	1.317	1.592	1.676
86	0.991	0.827	1.098	1.134
87	0.747	0.672	0.743	0.760
88	1.054	1.003	1.093	1.052
89	0.904	0.898	0.847	0.828
90	0.982	1.104	1.034	0.999
91	1.084	1.125	1.129	1.138
92	0.982	0.882	0.982	0.999
93	1.163	1.225	1.138	1.110
94	0.861	1.128	0.863	0.854
95	1.042	0.943	1.389	1.370
96	1.153	1.018	1.449	1.602
97	1.061	1.415	1.361	1.142
98	1.046	1.106	1.077	1.127
99	1.065	1.002	1.077	1.090
100	0.782	0.672	0.868	0.833

NC : Not Considered

Table A.4.20 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Inter-story Drift Ratio for Frame 'F5S2B'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	0.963	0.963	1.544	1.739	51	0.896	0.793	1.033	1.040
2	1.021	1.020	1.579	1.715	52	1.065	1.029	1.079	1.104
3	0.988	0.976	1.186	1.221	53	0.872	0.836	1.014	1.070
4	0.983	0.984	0.924	0.926	54	NC	NC	NC	NC
5	0.975	0.980	1.134	1.107	55	0.932	0.848	1.109	1.036
6	0.848	0.848	0.782	0.826	56	0.411	0.357	0.370	0.376
7	0.743	0.808	1.018	1.003	57	0.681	0.854	0.975	1.086
8	0.647	0.684	1.229	1.276	58	1.180	0.807	1.329	1.161
9	1.009	1.221	0.949	0.900	59	0.913	0.777	0.965	0.986
10	0.981	1.368	1.028	1.118	60	0.834	0.784	1.115	1.120
11	0.893	1.002	0.901	0.914	61	0.784	0.645	1.065	1.058
12	0.741	0.745	1.015	1.013	62	1.051	1.402	1.174	1.134
13	0.725	0.684	0.942	1.021	63	1.002	1.123	1.413	1.412
14	0.754	0.583	0.901	0.987	64	1.034	0.929	1.009	0.996
15	0.899	0.936	1.321	1.259	65	0.825	0.615	0.956	0.997
16	0.933	0.903	0.960	0.968	66	1.091	1.219	1.211	1.306
17	0.633	0.565	1.003	1.094	67	0.994	1.025	1.110	1.137
18	0.822	1.200	0.872	0.880	68	0.879	0.941	1.062	1.059
19	0.749	0.628	0.957	1.069	69	1.112	1.261	1.334	1.315
20	0.825	0.435	0.760	0.810	70	0.882	0.683	0.882	0.902
21	0.921	1.027	1.015	1.031	71	0.961	1.458	1.049	1.023
22	0.875	0.905	0.969	0.988	72	0.878	0.757	0.971	0.991
23	0.862	1.000	1.087	1.029	73	0.851	0.692	0.916	0.952
24	0.794	1.014	1.393	1.488	74	1.090	1.339	1.537	1.488
25	0.685	0.658	0.944	1.053	75	1.052	1.334	1.202	1.194
26	0.856	0.799	1.103	1.132	76	0.877	0.688	0.964	0.995
27	0.987	1.065	1.028	1.028	77	0.599	0.647	0.442	0.487
28	0.743	0.469	0.715	0.763	78	1.093	1.232	1.277	1.254
29	0.828	0.749	0.833	0.922	79	0.969	1.051	1.087	1.100
30	0.923	1.045	0.724	0.719	80	0.752	0.722	0.671	0.673
31	1.046	1.444	1.103	1.024	81	NC	NC	NC	NC
32	0.994	1.145	0.953	0.987	82	0.938	0.721	1.007	0.990
33	0.918	0.993	0.902	0.886	83	1.053	1.186	1.171	1.162
34	0.961	0.853	1.158	1.272	84	0.973	0.942	0.997	0.997
35	0.804	0.686	1.019	1.044	85	1.279	1.235	1.518	1.608
36	0.970	1.251	1.032	1.006	86	0.919	0.757	1.025	1.060
37	0.839	0.898	0.982	0.899	87	0.901	0.805	0.896	0.918
38	0.863	0.873	0.996	1.053	88	1.017	0.965	1.057	1.014
39	0.676	0.782	0.690	0.675	89	0.722	0.717	0.674	0.657
40	0.911	0.706	1.001	1.032	90	1.012	1.146	1.068	1.030
41	1.015	0.899	1.319	1.344	91	1.069	1.110	1.113	1.123
42	0.953	1.205	1.062	1.038	92	0.901	0.801	0.902	0.919
43	1.000	0.815	1.111	1.064	93	1.055	1.117	1.031	1.004
44	0.693	0.634	0.830	0.876	94	0.858	1.143	0.860	0.850
45	0.780	0.863	0.975	0.993	95	1.003	0.902	1.365	1.345
46	0.982	1.027	0.962	0.970	96	1.234	1.081	1.575	1.751
47	0.792	0.542	0.995	1.088	97	1.073	1.473	1.413	1.164
48	0.866	0.680	0.965	1.007	98	1.064	1.129	1.098	1.152
49	0.898	0.743	1.011	1.058	99	0.970	0.909	0.982	0.995
50	0.972	0.947	0.919	0.893	100	0.343	0.292	0.384	0.368

NC : Not Considered

Table A.4.21 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Base Shear for Frame 'F5S2B'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	0.742	0.741	1.188	1.338	51	0.932	0.919	0.946	0.947
2	1.036	1.035	1.628	1.774	52	1.008	1.004	1.009	1.011
3	0.971	0.961	1.125	1.152	53	0.926	0.893	1.055	1.105
4	0.932	0.932	0.874	0.876	54	NC	NC	NC	NC
5	0.863	0.867	0.978	0.959	55	0.904	0.846	0.971	0.951
6	0.874	0.874	0.811	0.854	56	1.064	1.050	1.054	1.055
7	0.777	0.831	1.005	0.992	57	0.729	0.887	0.996	1.080
8	0.694	0.727	1.200	1.240	58	0.999	0.961	1.010	0.997
9	1.045	1.230	0.993	0.950	59	0.866	0.878	0.867	0.868
10	1.133	1.491	1.176	1.260	60	0.883	0.846	0.973	0.974
11	0.887	0.973	0.894	0.904	61	0.918	0.781	1.021	1.020
12	0.784	0.787	1.024	1.022	62	1.015	1.042	1.026	1.023
13	0.791	0.752	0.958	0.988	63	0.985	0.994	0.996	0.996
14	0.878	0.735	0.921	0.933	64	0.921	0.910	0.919	0.918
15	0.850	0.878	1.164	1.119	65	1.040	0.805	1.181	1.219
16	0.994	0.968	1.019	1.026	66	0.993	1.000	1.000	1.009
17	0.671	0.610	0.997	1.076	67	0.971	0.974	0.979	0.981
18	0.826	1.128	0.866	0.873	68	0.988	0.994	1.003	1.003
19	0.926	0.823	0.988	0.997	69	0.921	0.930	0.933	0.933
20	0.875	0.712	0.867	0.873	70	0.920	0.899	0.920	0.921
21	0.913	1.003	0.994	1.007	71	1.009	1.075	1.035	1.028
22	0.875	0.894	0.927	0.935	72	0.901	0.851	0.918	0.921
23	0.883	0.999	1.073	1.024	73	0.910	0.894	0.917	0.920
24	0.823	1.001	1.293	1.365	74	0.953	0.970	0.984	0.981
25	0.682	0.659	0.900	0.990	75	0.964	0.955	0.968	0.968
26	0.935	0.918	0.964	0.966	76	0.905	0.847	0.915	0.914
27	0.968	1.034	1.003	1.003	77	0.848	0.858	0.859	0.850
28	0.905	0.650	0.892	0.912	78	0.891	0.899	0.902	0.901
29	0.925	0.895	0.927	0.944	79	1.012	1.022	1.025	1.026
30	1.057	1.169	0.866	0.862	80	1.013	1.010	1.005	1.005
31	0.973	1.064	1.000	0.962	81	NC	NC	NC	NC
32	0.923	1.014	0.889	0.917	82	1.015	1.015	1.006	1.003
33	1.071	1.145	1.056	1.041	83	1.034	1.036	1.041	1.040
34	0.908	0.821	1.066	1.156	84	0.938	0.934	0.936	0.938
35	0.871	0.758	1.034	1.047	85	0.916	0.924	0.903	0.894
36	0.968	1.208	1.022	1.000	86	0.921	0.906	0.931	0.934
37	0.976	0.983	0.991	0.983	87	0.924	0.914	0.924	0.926
38	0.929	0.934	0.968	0.977	88	0.962	0.957	0.965	0.962
39	0.690	0.777	0.702	0.689	89	0.871	0.870	0.865	0.863
40	0.934	0.806	0.955	0.960	90	1.015	1.024	1.020	1.016
41	1.017	1.009	1.047	1.049	91	0.948	0.954	0.954	0.954
42	1.123	1.375	1.234	1.210	92	0.896	0.884	0.896	0.898
43	0.955	0.938	0.966	0.962	93	0.886	0.883	0.889	0.891
44	0.916	0.901	0.931	0.937	94	0.999	1.015	0.999	0.998
45	0.905	0.919	0.926	0.928	95	0.907	0.900	0.889	0.891
46	0.971	1.009	0.955	0.962	96	0.979	0.968	0.999	1.002
47	0.820	0.591	0.986	1.031	97	0.915	0.947	0.944	0.923
48	0.871	0.712	0.923	0.938	98	0.934	0.940	0.937	0.941
49	1.012	0.949	1.030	1.036	99	0.933	0.927	0.934	0.935
50	0.893	0.891	0.888	0.885	100	0.970	0.955	0.978	0.975

NC : Not Considered

Table A.4.22 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Top Displacement for Frame 'F5S2B'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	1.605	1.809	51	0.895	1.138	1.146
2	0.999	1.558	1.695	52	0.968	1.012	1.034
3	0.988	1.187	1.221	53	0.959	1.161	1.224
4	1.000	0.939	0.941	54	NC	NC	NC
5	1.005	1.156	1.130	55	0.914	1.158	1.094
6	1.000	0.922	0.975	56	0.875	0.907	0.920
7	1.084	1.354	1.334	57	1.251	1.429	1.586
8	1.055	1.882	1.954	58	0.704	1.118	0.985
9	1.207	0.942	0.894	59	0.862	1.056	1.077
10	1.381	1.046	1.134	60	0.943	1.272	1.277
11	1.116	1.009	1.023	61	0.823	1.292	1.284
12	1.005	1.362	1.360	62	1.310	1.109	1.073
13	0.943	1.284	1.373	63	1.112	1.383	1.382
14	0.785	1.156	1.248	64	0.908	0.978	0.967
15	1.039	1.441	1.377	65	0.746	1.160	1.207
16	0.969	1.029	1.037	66	1.110	1.103	1.184
17	0.894	1.576	1.721	67	1.029	1.108	1.134
18	1.443	1.058	1.068	68	1.060	1.183	1.180
19	0.849	1.223	1.345	69	1.125	1.186	1.170
20	0.573	0.930	0.983	70	0.787	0.999	1.022
21	1.115	1.103	1.120	71	1.425	1.074	1.053
22	1.031	1.094	1.113	72	0.884	1.085	1.103
23	1.156	1.256	1.189	73	0.824	1.072	1.111
24	1.260	1.706	1.819	74	1.210	1.378	1.337
25	0.961	1.374	1.534	75	1.250	1.136	1.129
26	0.946	1.239	1.268	76	0.819	1.084	1.115
27	1.080	1.042	1.042	77	1.071	0.760	0.831
28	0.646	0.969	1.022	78	1.118	1.156	1.137
29	0.921	1.005	1.092	79	1.076	1.110	1.122
30	1.124	0.794	0.789	80	0.963	0.900	0.901
31	1.306	1.047	0.982	81	NC	NC	NC
32	1.141	0.958	0.993	82	0.781	1.067	1.049
33	1.081	0.984	0.966	83	1.119	1.105	1.097
34	0.889	1.203	1.320	84	0.972	1.022	1.021
35	0.853	1.253	1.279	85	0.967	1.170	1.231
36	1.290	1.064	1.037	86	0.835	1.108	1.144
37	1.063	1.156	1.065	87	0.900	0.995	1.018
38	1.010	1.125	1.177	88	0.952	1.037	0.997
39	1.150	1.020	0.999	89	0.994	0.937	0.916
40	0.795	1.080	1.107	90	1.124	1.052	1.017
41	0.898	1.271	1.293	91	1.038	1.041	1.050
42	1.265	1.114	1.089	92	0.899	1.001	1.018
43	0.831	1.100	1.057	93	1.053	0.979	0.954
44	0.930	1.168	1.226	94	1.311	1.002	0.992
45	1.087	1.210	1.230	95	0.905	1.333	1.315
46	1.045	0.980	0.988	96	0.882	1.256	1.389
47	0.687	1.253	1.352	97	1.334	1.284	1.077
48	0.787	1.099	1.140	98	1.057	1.029	1.077
49	0.855	1.103	1.147	99	0.941	1.011	1.024
50	0.976	0.949	0.924	100	0.859	1.110	1.065

NC : Not Considered

Table A.4.23 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Inter-story Drift Ratio for Frame 'F5S2B'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	1.604	1.806	51	0.885	1.152	1.161
2	0.999	1.547	1.680	52	0.966	1.013	1.036
3	0.988	1.200	1.235	53	0.958	1.163	1.227
4	1.000	0.939	0.941	54	NC	NC	NC
5	1.005	1.163	1.135	55	0.911	1.191	1.112
6	1.000	0.922	0.975	56	0.868	0.901	0.915
7	1.087	1.370	1.349	57	1.253	1.432	1.594
8	1.057	1.901	1.974	58	0.684	1.126	0.984
9	1.210	0.941	0.892	59	0.852	1.057	1.080
10	1.394	1.048	1.139	60	0.940	1.336	1.342
11	1.123	1.009	1.024	61	0.822	1.358	1.349
12	1.005	1.369	1.366	62	1.334	1.118	1.080
13	0.943	1.299	1.408	63	1.121	1.410	1.410
14	0.773	1.194	1.309	64	0.899	0.976	0.963
15	1.040	1.469	1.399	65	0.745	1.159	1.207
16	0.968	1.030	1.038	66	1.117	1.110	1.196
17	0.892	1.583	1.728	67	1.031	1.117	1.144
18	1.461	1.061	1.071	68	1.070	1.208	1.205
19	0.839	1.278	1.427	69	1.134	1.200	1.183
20	0.528	0.922	0.982	70	0.774	0.999	1.023
21	1.115	1.103	1.120	71	1.517	1.092	1.065
22	1.034	1.107	1.129	72	0.863	1.106	1.128
23	1.159	1.261	1.193	73	0.814	1.077	1.119
24	1.277	1.754	1.874	74	1.228	1.410	1.365
25	0.960	1.378	1.538	75	1.268	1.143	1.135
26	0.934	1.289	1.323	76	0.784	1.099	1.134
27	1.079	1.041	1.042	77	1.079	0.737	0.812
28	0.631	0.963	1.028	78	1.127	1.168	1.148
29	0.904	1.006	1.114	79	1.084	1.122	1.135
30	1.132	0.784	0.779	80	0.961	0.893	0.895
31	1.381	1.055	0.979	81	NC	NC	NC
32	1.152	0.958	0.993	82	0.769	1.074	1.056
33	1.082	0.983	0.966	83	1.126	1.112	1.104
34	0.888	1.206	1.324	84	0.968	1.025	1.024
35	0.853	1.266	1.298	85	0.965	1.187	1.257
36	1.290	1.064	1.038	86	0.824	1.116	1.154
37	1.070	1.171	1.071	87	0.894	0.994	1.019
38	1.012	1.155	1.221	88	0.949	1.039	0.997
39	1.157	1.021	0.999	89	0.993	0.934	0.911
40	0.775	1.099	1.133	90	1.133	1.056	1.018
41	0.886	1.300	1.325	91	1.038	1.042	1.050
42	1.264	1.114	1.090	92	0.889	1.001	1.020
43	0.815	1.111	1.064	93	1.058	0.977	0.951
44	0.914	1.198	1.264	94	1.332	1.002	0.991
45	1.106	1.249	1.272	95	0.899	1.361	1.341
46	1.046	0.980	0.988	96	0.876	1.276	1.419
47	0.685	1.257	1.374	97	1.372	1.317	1.085
48	0.786	1.114	1.163	98	1.061	1.031	1.082
49	0.828	1.127	1.178	99	0.937	1.012	1.025
50	0.974	0.945	0.918	100	0.850	1.119	1.070

NC : Not Considered

Table A.4.24 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Base Shear for Frame 'F5S2B'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	1.602	1.804	51	0.986	1.015	1.016
2	0.999	1.572	1.713	52	0.997	1.001	1.003
3	0.990	1.159	1.186	53	0.964	1.139	1.193
4	1.000	0.938	0.940	54	NC	NC	NC
5	1.005	1.134	1.112	55	0.935	1.074	1.052
6	1.000	0.928	0.977	56	0.987	0.990	0.992
7	1.070	1.293	1.277	57	1.216	1.365	1.480
8	1.047	1.728	1.786	58	0.963	1.011	0.998
9	1.177	0.950	0.909	59	1.015	1.002	1.002
10	1.317	1.039	1.112	60	0.958	1.102	1.103
11	1.097	1.008	1.019	61	0.851	1.113	1.111
12	1.004	1.306	1.304	62	1.027	1.011	1.008
13	0.951	1.211	1.249	63	1.009	1.011	1.011
14	0.837	1.048	1.062	64	0.988	0.998	0.996
15	1.033	1.369	1.317	65	0.774	1.136	1.172
16	0.973	1.025	1.032	66	1.007	1.007	1.015
17	0.908	1.486	1.603	67	1.003	1.008	1.010
18	1.367	1.049	1.057	68	1.006	1.016	1.015
19	0.889	1.067	1.077	69	1.009	1.013	1.012
20	0.814	0.992	0.998	70	0.978	1.000	1.002
21	1.099	1.089	1.103	71	1.065	1.025	1.019
22	1.022	1.059	1.069	72	0.945	1.019	1.022
23	1.132	1.216	1.160	73	0.982	1.007	1.011
24	1.216	1.571	1.659	74	1.018	1.032	1.029
25	0.966	1.319	1.451	75	0.991	1.004	1.004
26	0.982	1.031	1.034	76	0.936	1.012	1.010
27	1.068	1.036	1.036	77	1.012	1.012	1.002
28	0.719	0.987	1.008	78	1.009	1.011	1.010
29	0.967	1.002	1.020	79	1.009	1.013	1.014
30	1.106	0.819	0.815	80	0.997	0.992	0.992
31	1.094	1.027	0.989	81	NC	NC	NC
32	1.099	0.964	0.994	82	1.000	0.992	0.988
33	1.069	0.986	0.971	83	1.002	1.007	1.006
34	0.904	1.174	1.273	84	0.996	0.998	1.000
35	0.871	1.188	1.202	85	1.009	0.985	0.976
36	1.248	1.056	1.033	86	0.984	1.012	1.015
37	1.007	1.016	1.007	87	0.989	0.999	1.002
38	1.005	1.042	1.051	88	0.995	1.003	1.000
39	1.126	1.017	0.999	89	0.999	0.994	0.991
40	0.863	1.023	1.028	90	1.009	1.005	1.002
41	0.992	1.029	1.031	91	1.007	1.007	1.007
42	1.225	1.099	1.078	92	0.986	1.000	1.002
43	0.982	1.012	1.007	93	0.996	1.003	1.005
44	0.984	1.017	1.023	94	1.016	1.000	0.999
45	1.015	1.023	1.025	95	0.993	0.980	0.983
46	1.038	0.983	0.990	96	0.989	1.020	1.023
47	0.721	1.203	1.258	97	1.035	1.031	1.009
48	0.817	1.060	1.078	98	1.006	1.003	1.008
49	0.938	1.018	1.023	99	0.994	1.001	1.002
50	0.997	0.994	0.992	100	0.984	1.008	1.005

NC : Not Considered

Table A.4.25 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Top Displacement for Frame 'F5S4B'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	0.915	0.914	1.042	1.030	51	0.937	0.756	1.015	1.018
2	1.033	1.033	0.919	0.889	52	0.997	1.054	1.116	1.114
3	0.988	0.977	1.050	1.058	53	0.882	0.878	0.977	0.983
4	0.911	0.911	1.225	1.248	54	1.049	1.102	1.175	1.169
5	0.947	0.958	0.950	0.943	55	0.774	0.598	0.870	0.910
6	0.899	0.916	0.821	0.835	56	1.050	0.961	1.149	1.170
7	0.862	0.934	0.998	1.037	57	0.845	0.633	0.942	0.959
8	0.923	0.889	1.007	1.010	58	1.060	1.082	1.233	1.239
9	0.837	0.690	0.979	1.007	59	1.010	0.998	1.075	1.082
10	0.919	0.962	0.988	0.993	60	0.929	0.889	0.994	1.004
11	0.821	0.826	1.110	1.138	61	0.817	0.843	0.955	0.984
12	0.805	0.802	0.971	0.984	62	0.990	1.126	1.086	1.066
13	0.889	0.881	1.014	1.021	63	0.842	0.686	0.941	0.956
14	0.960	0.986	1.065	1.064	64	0.979	0.899	1.024	1.040
15	0.778	0.775	1.191	1.258	65	0.874	0.863	0.943	0.948
16	0.968	0.919	0.988	0.991	66	0.929	1.202	1.125	1.130
17	0.859	0.797	1.016	1.024	67	1.026	1.060	1.116	1.122
18	0.882	0.919	1.012	1.041	68	0.885	0.652	0.983	1.000
19	0.880	0.992	1.021	1.011	69	0.966	0.771	1.109	1.147
20	0.922	0.717	0.870	0.890	70	0.953	0.983	0.968	0.958
21	0.815	0.839	0.905	0.936	71	0.955	0.990	0.975	0.974
22	0.798	0.645	0.903	0.936	72	0.804	0.715	0.857	0.906
23	0.694	0.652	0.967	0.989	73	0.846	0.916	0.875	0.900
24	0.820	0.784	1.074	1.112	74	1.108	1.040	1.220	1.226
25	0.914	1.078	1.107	1.099	75	1.000	0.965	1.123	1.042
26	0.890	0.771	0.975	1.007	76	0.904	0.897	0.941	0.944
27	0.742	0.758	0.853	0.892	77	1.250	1.108	1.354	1.365
28	0.895	0.716	0.906	0.953	78	0.952	1.075	1.219	1.235
29	1.002	0.907	0.996	0.991	79	0.992	0.989	1.082	1.069
30	1.032	1.038	0.988	1.010	80	0.866	0.672	0.769	0.779
31	0.889	0.730	1.036	1.052	81	0.910	0.721	0.855	0.875
32	0.807	0.718	0.846	0.886	82	0.994	1.310	1.110	1.068
33	0.912	0.990	0.944	0.948	83	0.972	1.014	0.957	0.956
34	0.942	0.844	1.054	1.042	84	0.935	0.814	1.024	1.048
35	1.132	1.322	1.073	1.039	85	1.027	1.137	1.057	1.059
36	0.865	0.758	0.967	0.986	86	0.987	0.954	0.997	0.999
37	0.946	0.846	0.923	0.970	87	0.982	0.913	0.975	0.982
38	0.952	0.863	1.071	1.081	88	0.985	0.791	1.046	1.071
39	0.987	0.983	0.917	0.909	89	1.005	0.939	1.108	1.120
40	0.876	0.682	0.834	0.856	90	0.975	0.852	0.950	0.985
41	1.033	1.449	1.164	1.124	91	0.985	1.008	1.019	1.021
42	0.978	1.131	0.960	0.932	92	1.072	1.122	1.239	1.238
43	1.034	1.025	1.004	1.006	93	1.114	1.088	1.098	1.095
44	0.828	0.711	0.927	0.929	94	0.976	0.822	0.982	0.993
45	0.874	0.686	0.956	0.971	95	0.666	0.565	0.628	0.612
46	0.906	0.942	0.925	0.927	96	0.759	1.048	0.822	0.824
47	0.917	0.966	0.984	0.982	97	0.757	0.949	0.870	0.852
48	0.989	0.940	0.999	1.001	98	0.846	0.836	0.910	0.928
49	0.919	0.912	0.968	0.968	99	1.029	0.966	1.007	1.013
50	1.028	0.978	1.157	1.138	100	0.938	0.960	1.032	1.079

NC : Not Considered

Table A.4.26 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Inter-story Drift Ratio for Frame 'F5S4B'

EQ	MULTI	ATC	FEMA	75%Vy
1	0.918	0.918	1.046	1.033
2	0.989	0.989	0.879	0.850
3	1.009	0.997	1.075	1.084
4	0.871	0.871	1.171	1.193
5	0.955	0.967	0.959	0.951
6	0.749	0.765	0.683	0.695
7	0.872	0.947	1.014	1.055
8	0.922	0.888	1.008	1.011
9	0.879	0.723	1.030	1.060
10	0.952	0.998	1.026	1.031
11	0.790	0.796	1.079	1.107
12	0.792	0.790	0.958	0.970
13	0.909	0.901	1.043	1.052
14	0.964	0.995	1.087	1.086
15	0.763	0.760	1.185	1.253
16	0.931	0.884	0.951	0.954
17	0.872	0.809	1.033	1.041
18	0.889	0.927	1.024	1.054
19	0.898	1.017	1.049	1.039
20	0.891	0.678	0.838	0.858
21	0.811	0.835	0.902	0.933
22	0.769	0.618	0.884	0.921
23	0.686	0.643	0.960	0.983
24	0.780	0.745	1.029	1.066
25	0.907	1.072	1.101	1.093
26	0.882	0.760	0.976	1.013
27	0.764	0.781	0.879	0.920
28	0.904	0.701	0.916	0.969
29	1.010	0.903	1.004	0.997
30	0.555	0.559	0.532	0.544
31	0.874	0.714	1.037	1.056
32	0.799	0.711	0.838	0.878
33	0.810	0.880	0.838	0.842
34	0.939	0.841	1.053	1.041
35	1.150	1.345	1.090	1.054
36	0.888	0.777	0.994	1.013
37	0.938	0.832	0.914	0.963
38	0.960	0.857	1.096	1.107
39	0.502	0.500	0.465	0.460
40	0.870	0.660	0.821	0.847
41	1.067	1.564	1.219	1.172
42	0.976	1.131	0.958	0.929
43	1.039	1.029	1.005	1.007
44	0.850	0.721	0.957	0.959
45	0.863	0.658	0.955	0.972
46	0.830	0.864	0.848	0.849
47	0.952	1.003	1.021	1.019
48	0.933	0.885	0.943	0.945
49	0.960	0.951	1.019	1.019
50	0.977	0.924	1.108	1.088

EQ	MULTI	ATC	FEMA	75%Vy
51	0.916	0.724	0.997	1.000
52	1.027	1.090	1.158	1.156
53	0.909	0.904	1.008	1.014
54	1.045	1.099	1.172	1.166
55	0.765	0.589	0.869	0.915
56	1.020	0.933	1.116	1.136
57	0.841	0.628	0.950	0.969
58	1.047	1.069	1.223	1.229
59	0.956	0.945	1.012	1.019
60	0.973	0.931	1.043	1.053
61	0.809	0.836	0.960	0.992
62	0.983	1.138	1.092	1.069
63	0.868	0.700	0.972	0.987
64	1.019	0.923	1.071	1.090
65	0.890	0.879	0.961	0.966
66	0.937	1.240	1.155	1.160
67	1.034	1.068	1.125	1.131
68	0.873	0.617	0.976	0.994
69	0.988	0.783	1.135	1.173
70	0.925	0.954	0.939	0.929
71	0.972	1.007	0.992	0.991
72	0.797	0.697	0.856	0.909
73	0.796	0.867	0.826	0.850
74	1.122	1.049	1.241	1.247
75	1.045	1.009	1.175	1.090
76	0.929	0.920	0.971	0.974
77	1.197	1.073	1.275	1.283
78	0.904	1.025	1.163	1.179
79	1.018	1.014	1.115	1.101
80	0.912	0.710	0.813	0.824
81	0.957	0.776	0.904	0.923
82	1.027	1.328	1.140	1.100
83	0.964	1.007	0.949	0.948
84	0.967	0.825	1.072	1.099
85	1.060	1.170	1.091	1.094
86	0.987	0.953	0.997	1.000
87	0.966	0.897	0.958	0.966
88	0.979	0.785	1.037	1.061
89	0.966	0.901	1.062	1.073
90	1.009	0.873	0.981	1.019
91	1.022	1.044	1.055	1.056
92	1.072	1.126	1.248	1.247
93	1.161	1.135	1.145	1.142
94	1.007	0.855	1.013	1.024
95	0.662	0.558	0.624	0.607
96	0.741	1.052	0.810	0.812
97	0.747	0.966	0.876	0.856
98	0.852	0.841	0.919	0.938
99	1.028	0.963	1.006	1.011
100	0.904	0.925	0.995	1.040

NC : Not Considered

Table A.4.27 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Base Shear for Frame 'F5S4B'

EQ	MULTI	ATC	FEMA	75%Vy
1	0.884	0.884	1.020	1.007
2	0.924	0.924	0.816	0.787
3	1.011	1.001	1.069	1.076
4	0.806	0.806	1.078	1.098
5	0.915	0.926	0.919	0.912
6	0.791	0.806	0.724	0.736
7	0.874	0.941	1.000	1.036
8	0.936	0.904	1.015	1.018
9	0.955	0.797	1.108	1.137
10	1.078	1.125	1.153	1.158
11	0.767	0.771	1.014	1.038
12	0.802	0.800	0.957	0.969
13	0.943	0.934	1.056	1.062
14	0.987	1.002	1.039	1.039
15	0.771	0.768	1.140	1.199
16	0.874	0.833	0.891	0.894
17	0.928	0.865	1.087	1.095
18	0.988	1.026	1.122	1.152
19	0.949	1.055	1.077	1.070
20	0.907	0.840	0.895	0.900
21	0.764	0.785	0.843	0.870
22	0.858	0.710	0.934	0.952
23	0.704	0.664	0.960	0.981
24	0.748	0.717	0.962	0.994
25	0.903	1.055	1.081	1.075
26	0.901	0.793	0.963	0.982
27	0.754	0.769	0.859	0.896
28	0.899	0.807	0.903	0.918
29	1.036	0.991	1.034	1.031
30	0.473	0.476	0.454	0.464
31	0.931	0.777	1.034	1.043
32	0.810	0.726	0.846	0.884
33	0.791	0.853	0.816	0.820
34	0.936	0.844	1.039	1.028
35	1.165	1.347	1.108	1.074
36	0.958	0.846	1.064	1.083
37	0.969	0.938	0.963	0.974
38	1.000	0.943	1.053	1.057
39	0.457	0.455	0.427	0.423
40	0.914	0.761	0.889	0.902
41	1.052	1.269	1.146	1.119
42	1.160	1.330	1.141	1.109
43	1.045	1.040	1.027	1.028
44	0.997	0.951	1.024	1.024
45	0.924	0.785	0.961	0.966
46	0.641	0.665	0.654	0.655
47	0.827	0.868	0.883	0.881
48	0.845	0.807	0.851	0.853
49	1.083	1.078	1.114	1.115
50	0.963	0.947	0.995	0.991

EQ	MULTI	ATC	FEMA	75%Vy
51	0.946	0.878	0.965	0.966
52	0.998	1.015	1.031	1.031
53	0.805	0.801	0.886	0.892
54	1.011	1.019	1.030	1.029
55	0.803	0.631	0.876	0.902
56	0.951	0.938	0.964	0.966
57	0.918	0.704	0.994	1.005
58	0.967	0.972	0.995	0.996
59	0.907	0.906	0.912	0.913
60	1.015	0.974	1.081	1.090
61	0.801	0.824	0.903	0.919
62	0.929	0.983	0.969	0.962
63	1.005	0.957	1.024	1.027
64	0.967	0.925	0.986	0.992
65	0.741	0.733	0.797	0.800
66	1.042	1.132	1.113	1.115
67	1.053	1.059	1.067	1.068
68	0.936	0.800	0.966	0.970
69	0.905	0.865	0.924	0.928
70	0.912	0.915	0.914	0.912
71	1.098	1.135	1.119	1.118
72	0.865	0.819	0.887	0.904
73	0.870	0.886	0.876	0.882
74	0.887	0.873	0.907	0.908
75	1.111	1.105	1.131	1.119
76	0.826	0.822	0.850	0.851
77	0.966	0.954	0.971	0.972
78	0.870	0.892	0.910	0.912
79	1.310	1.308	1.342	1.338
80	0.976	0.941	0.960	0.962
81	1.003	0.979	0.997	1.000
82	1.010	1.033	1.022	1.019
83	1.024	1.032	1.021	1.021
84	1.071	0.981	1.115	1.125
85	0.983	0.996	0.987	0.987
86	1.037	1.029	1.038	1.039
87	0.938	0.927	0.937	0.938
88	0.891	0.861	0.899	0.901
89	0.829	0.820	0.840	0.841
90	1.020	0.982	1.014	1.022
91	0.991	0.994	0.995	0.995
92	0.978	0.988	1.010	1.009
93	0.994	0.991	0.992	0.992
94	0.917	0.898	0.918	0.918
95	0.862	0.832	0.853	0.848
96	0.925	1.027	0.956	0.957
97	0.746	0.827	0.800	0.793
98	0.992	0.989	1.009	1.012
99	0.967	0.955	0.963	0.964
100	0.892	0.895	0.906	0.911

NC : Not Considered

Table A.4.28 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Top Displacement for Frame 'F5S4B'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	1.140	1.126	51	0.807	1.084	1.086
2	1.000	0.889	0.861	52	1.056	1.119	1.116
3	0.989	1.063	1.071	53	0.995	1.108	1.115
4	1.000	1.344	1.370	54	1.051	1.120	1.115
5	1.012	1.004	0.996	55	0.772	1.123	1.175
6	1.019	0.913	0.929	56	0.915	1.094	1.115
7	1.083	1.157	1.202	57	0.750	1.116	1.136
8	0.964	1.091	1.095	58	1.020	1.163	1.168
9	0.825	1.170	1.204	59	0.988	1.064	1.072
10	1.047	1.076	1.081	60	0.957	1.070	1.080
11	1.006	1.352	1.386	61	1.032	1.169	1.204
12	0.997	1.206	1.222	62	1.138	1.097	1.077
13	0.991	1.141	1.149	63	0.815	1.118	1.136
14	1.027	1.110	1.109	64	0.918	1.046	1.062
15	0.996	1.530	1.616	65	0.988	1.080	1.085
16	0.950	1.021	1.024	66	1.294	1.210	1.216
17	0.928	1.183	1.193	67	1.033	1.087	1.093
18	1.042	1.148	1.181	68	0.736	1.110	1.129
19	1.127	1.160	1.149	69	0.798	1.148	1.188
20	0.778	0.944	0.965	70	1.031	1.015	1.005
21	1.029	1.111	1.149	71	1.036	1.020	1.020
22	0.809	1.132	1.173	72	0.890	1.066	1.127
23	0.939	1.393	1.425	73	1.084	1.034	1.064
24	0.956	1.310	1.356	74	0.939	1.101	1.106
25	1.179	1.211	1.203	75	0.965	1.124	1.043
26	0.866	1.095	1.132	76	0.992	1.041	1.043
27	1.021	1.149	1.201	77	0.886	1.084	1.092
28	0.800	1.012	1.065	78	1.128	1.280	1.297
29	0.906	0.995	0.989	79	0.996	1.090	1.077
30	1.006	0.958	0.979	80	0.775	0.887	0.899
31	0.820	1.165	1.183	81	0.793	0.939	0.962
32	0.890	1.048	1.098	82	1.318	1.116	1.075
33	1.085	1.034	1.039	83	1.043	0.985	0.984
34	0.896	1.119	1.106	84	0.870	1.095	1.120
35	1.167	0.948	0.917	85	1.108	1.029	1.032
36	0.876	1.118	1.140	86	0.967	1.010	1.013
37	0.894	0.976	1.025	87	0.929	0.992	1.000
38	0.906	1.125	1.135	88	0.803	1.062	1.087
39	0.996	0.929	0.920	89	0.933	1.102	1.114
40	0.779	0.952	0.977	90	0.873	0.974	1.010
41	1.403	1.127	1.088	91	1.023	1.035	1.036
42	1.157	0.982	0.953	92	1.047	1.156	1.155
43	0.991	0.971	0.973	93	0.977	0.986	0.983
44	0.858	1.119	1.121	94	0.843	1.006	1.017
45	0.785	1.095	1.112	95	0.849	0.944	0.920
46	1.040	1.021	1.023	96	1.381	1.084	1.086
47	1.054	1.073	1.070	97	1.254	1.149	1.126
48	0.951	1.010	1.012	98	0.988	1.075	1.097
49	0.992	1.053	1.053	99	0.938	0.978	0.984
50	0.951	1.125	1.107	100	1.023	1.100	1.150

NC : Not Considered

Table A.4.29 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Inter-story Drift Ratio for Frame 'F5S4B'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	1.139	1.125	51	0.791	1.089	1.092
2	1.000	0.889	0.860	52	1.061	1.127	1.125
3	0.988	1.066	1.074	53	0.995	1.109	1.116
4	1.000	1.344	1.370	54	1.051	1.121	1.115
5	1.012	1.004	0.996	55	0.770	1.136	1.196
6	1.020	0.911	0.927	56	0.915	1.095	1.114
7	1.087	1.163	1.210	57	0.746	1.130	1.153
8	0.963	1.093	1.096	58	1.021	1.168	1.173
9	0.822	1.172	1.206	59	0.989	1.059	1.066
10	1.048	1.078	1.083	60	0.957	1.072	1.082
11	1.006	1.365	1.400	61	1.033	1.186	1.227
12	0.997	1.208	1.225	62	1.157	1.111	1.088
13	0.991	1.147	1.157	63	0.806	1.120	1.138
14	1.032	1.127	1.126	64	0.906	1.051	1.070
15	0.996	1.553	1.643	65	0.988	1.081	1.086
16	0.949	1.021	1.025	66	1.324	1.233	1.239
17	0.928	1.185	1.194	67	1.033	1.088	1.094
18	1.044	1.153	1.186	68	0.707	1.119	1.139
19	1.132	1.168	1.156	69	0.792	1.149	1.187
20	0.761	0.941	0.963	70	1.031	1.015	1.005
21	1.030	1.113	1.151	71	1.037	1.021	1.020
22	0.804	1.150	1.198	72	0.875	1.074	1.141
23	0.938	1.401	1.434	73	1.088	1.037	1.068
24	0.955	1.318	1.366	74	0.935	1.106	1.111
25	1.181	1.213	1.205	75	0.965	1.124	1.043
26	0.862	1.106	1.148	76	0.991	1.046	1.049
27	1.021	1.150	1.203	77	0.897	1.065	1.072
28	0.776	1.013	1.072	78	1.133	1.286	1.304
29	0.894	0.994	0.988	79	0.996	1.096	1.082
30	1.006	0.958	0.979	80	0.779	0.892	0.903
31	0.817	1.186	1.208	81	0.812	0.945	0.965
32	0.889	1.048	1.099	82	1.293	1.111	1.071
33	1.087	1.035	1.040	83	1.044	0.984	0.983
34	0.895	1.121	1.108	84	0.853	1.108	1.136
35	1.169	0.947	0.916	85	1.103	1.029	1.032
36	0.875	1.119	1.141	86	0.966	1.011	1.013
37	0.887	0.974	1.027	87	0.929	0.992	1.000
38	0.893	1.142	1.154	88	0.802	1.060	1.085
39	0.996	0.926	0.917	89	0.933	1.099	1.111
40	0.759	0.944	0.974	90	0.865	0.973	1.010
41	1.465	1.142	1.098	91	1.021	1.032	1.033
42	1.159	0.982	0.952	92	1.050	1.164	1.163
43	0.990	0.967	0.969	93	0.978	0.986	0.984
44	0.848	1.126	1.128	94	0.849	1.005	1.016
45	0.762	1.107	1.127	95	0.844	0.942	0.917
46	1.041	1.022	1.024	96	1.421	1.094	1.096
47	1.054	1.073	1.071	97	1.293	1.172	1.146
48	0.949	1.011	1.013	98	0.987	1.079	1.101
49	0.991	1.061	1.062	99	0.936	0.978	0.983
50	0.946	1.134	1.114	100	1.023	1.101	1.150

NC : Not Considered

Table A.4.30 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Base Shear for Frame 'F5S4B'

EQ	ATC	FEMA	75%Vy
1	1.000	1.154	1.139
2	1.000	0.882	0.852
3	0.990	1.057	1.065
4	1.000	1.337	1.362
5	1.011	1.004	0.997
6	1.019	0.915	0.931
7	1.076	1.144	1.185
8	0.966	1.085	1.088
9	0.835	1.159	1.190
10	1.043	1.070	1.075
11	1.006	1.322	1.353
12	0.997	1.192	1.207
13	0.991	1.120	1.126
14	1.015	1.053	1.052
15	0.997	1.478	1.555
16	0.953	1.019	1.023
17	0.933	1.172	1.180
18	1.039	1.137	1.167
19	1.111	1.135	1.128
20	0.926	0.987	0.993
21	1.028	1.104	1.140
22	0.827	1.088	1.109
23	0.943	1.363	1.393
24	0.959	1.286	1.328
25	1.168	1.197	1.190
26	0.880	1.068	1.090
27	1.020	1.139	1.188
28	0.898	1.004	1.022
29	0.957	0.998	0.996
30	1.006	0.959	0.980
31	0.834	1.111	1.121
32	0.896	1.045	1.092
33	1.078	1.032	1.036
34	0.902	1.110	1.098
35	1.157	0.951	0.922
36	0.883	1.111	1.131
37	0.968	0.993	1.006
38	0.943	1.053	1.057
39	0.996	0.935	0.927
40	0.833	0.972	0.987
41	1.207	1.090	1.064
42	1.146	0.983	0.956
43	0.995	0.983	0.984
44	0.953	1.027	1.027
45	0.849	1.040	1.046
46	1.037	1.020	1.021
47	1.050	1.068	1.066
48	0.956	1.008	1.010
49	0.995	1.029	1.030
50	0.983	1.033	1.029
51	0.927	1.020	1.020
52	1.017	1.033	1.033
53	0.995	1.101	1.108
54	1.008	1.018	1.017
55	0.786	1.091	1.123
56	0.986	1.013	1.016
57	0.767	1.083	1.094
58	1.005	1.029	1.030
59	0.998	1.006	1.006
60	0.959	1.064	1.073
61	1.028	1.128	1.148
62	1.058	1.043	1.035
63	0.952	1.019	1.022
64	0.956	1.019	1.026
65	0.989	1.075	1.080
66	1.086	1.069	1.070
67	1.005	1.013	1.014
68	0.854	1.032	1.037
69	0.956	1.021	1.026
70	1.004	1.002	1.001
71	1.034	1.019	1.018
72	0.946	1.025	1.044
73	1.018	1.007	1.014
74	0.985	1.023	1.024
75	0.995	1.017	1.007
76	0.994	1.029	1.030
77	0.988	1.006	1.006
78	1.025	1.046	1.048
79	0.999	1.025	1.021
80	0.965	0.984	0.986
81	0.976	0.994	0.997
82	1.023	1.012	1.008
83	1.008	0.997	0.997
84	0.917	1.041	1.050
85	1.014	1.004	1.005
86	0.993	1.002	1.002
87	0.988	0.999	1.000
88	0.966	1.008	1.012
89	0.990	1.013	1.015
90	0.964	0.994	1.002
91	1.002	1.003	1.004
92	1.010	1.032	1.032
93	0.997	0.998	0.998
94	0.979	1.000	1.001
95	0.966	0.990	0.984
96	1.110	1.034	1.034
97	1.109	1.072	1.063
98	0.997	1.017	1.020
99	0.988	0.996	0.997
100	1.003	1.015	1.021

NC : Not Considered

Table A.4.31 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Top Displacement for Frame 'F5S7B'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	0.977	0.977	0.938	1.138	51	0.925	0.603	0.948	1.037
2	0.984	0.984	1.535	1.654	52	1.033	1.102	1.064	1.061
3	0.976	0.940	1.199	1.250	53	0.884	0.863	0.995	1.012
4	0.978	0.977	0.975	0.879	54	0.843	0.759	0.847	0.911
5	0.821	0.892	0.987	1.005	55	0.994	0.910	1.076	1.078
6	0.917	0.957	0.702	0.658	56	0.996	0.941	1.010	1.026
7	0.700	0.731	0.941	1.038	57	0.865	1.119	1.060	0.984
8	0.805	0.909	1.216	1.170	58	NC	NC	NC	NC
9	0.901	1.383	1.013	0.938	59	0.998	0.780	1.005	1.072
10	0.892	1.222	0.872	0.725	60	0.859	0.709	0.972	1.119
11	0.850	0.936	0.906	0.870	61	0.896	0.817	1.056	1.061
12	0.780	0.822	1.026	1.180	62	1.011	1.150	1.260	1.270
13	0.930	0.869	1.107	1.228	63	0.848	0.394	0.997	1.084
14	0.818	0.687	1.027	1.111	64	0.973	0.816	0.997	1.040
15	0.890	1.010	0.937	0.978	65	0.966	0.809	0.953	1.069
16	0.921	0.938	1.080	1.122	66	1.059	1.313	1.607	1.341
17	0.831	0.894	1.170	1.291	67	1.023	1.090	1.321	1.291
18	0.798	0.905	0.956	0.880	68	0.897	1.088	1.100	1.046
19	0.738	0.558	0.928	1.070	69	1.045	1.090	1.292	1.355
20	0.893	0.694	0.928	1.042	70	1.022	0.777	1.083	1.169
21	0.863	0.748	1.086	1.042	71	1.002	0.993	1.092	1.023
22	0.951	0.951	1.044	1.060	72	0.985	1.193	0.999	1.085
23	0.839	0.937	1.158	1.167	73	NC	NC	NC	NC
24	0.742	0.839	1.029	1.037	74	0.940	0.810	0.897	0.999
25	0.994	1.062	1.048	1.214	75	1.067	0.760	1.149	1.387
26	0.890	0.808	1.035	1.116	76	0.785	0.769	0.909	1.051
27	0.959	1.019	0.993	0.982	77	0.958	0.719	1.105	1.069
28	0.935	0.884	0.932	1.028	78	0.954	0.988	1.013	1.032
29	0.916	1.075	1.015	1.091	79	1.000	0.797	0.959	1.020
30	0.784	0.879	1.084	0.966	80	NC	NC	NC	NC
31	0.937	0.675	1.240	1.188	81	NC	NC	NC	NC
32	0.848	1.029	1.018	1.066	82	NC	NC	NC	NC
33	0.944	0.965	0.961	0.945	83	0.961	1.056	1.107	1.038
34	1.023	1.252	0.924	1.018	84	0.984	1.163	1.188	1.131
35	0.794	0.618	1.065	1.198	85	0.858	0.840	0.970	1.047
36	0.936	1.251	1.085	1.036	86	0.921	0.683	0.955	1.021
37	0.876	1.122	0.985	1.090	87	NC	NC	NC	NC
38	0.966	0.719	1.249	1.350	88	1.041	1.032	1.177	1.130
39	0.890	1.001	0.873	0.862	89	0.954	0.653	0.825	0.881
40	0.900	0.872	1.012	1.130	90	1.020	0.982	1.157	1.141
41	0.796	0.794	1.173	1.031	91	NC	NC	NC	NC
42	1.001	1.191	1.037	1.009	92	0.996	1.077	0.982	1.079
43	1.014	0.805	1.189	1.184	93	1.057	0.781	1.071	1.166
44	0.766	0.871	0.904	1.095	94	NC	NC	NC	NC
45	0.984	0.688	1.233	1.303	95	1.036	1.389	0.934	0.990
46	0.915	1.079	0.900	0.878	96	0.902	1.720	1.319	1.166
47	0.999	1.026	1.061	1.123	97	1.104	1.458	1.406	1.658
48	0.812	0.856	0.976	1.057	98	0.919	0.811	0.905	1.049
49	0.961	1.011	1.188	1.202	99	NC	NC	NC	NC
50	0.963	0.744	1.015	1.101	100	1.036	1.428	1.254	1.058

NC : Not Considered

Table A.4.32 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Inter-story Drift Ratio for Frame 'F5S7B'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	1.005	1.005	0.965	1.172	51	0.910	0.562	0.935	1.036
2	1.009	1.009	1.571	1.690	52	1.056	1.129	1.088	1.085
3	0.972	0.936	1.196	1.247	53	0.864	0.844	0.980	0.998
4	1.016	1.015	1.012	0.913	54	0.812	0.721	0.815	0.887
5	0.831	0.903	1.000	1.018	55	0.909	0.825	0.994	0.997
6	0.904	0.944	0.692	0.648	56	0.977	0.924	0.990	1.005
7	0.707	0.738	0.951	1.050	57	0.829	1.092	1.030	0.951
8	0.803	0.907	1.215	1.169	58	NC	NC	NC	NC
9	0.926	1.469	1.051	0.967	59	0.845	0.660	0.851	0.906
10	0.932	1.307	0.910	0.757	60	0.845	0.689	0.969	1.136
11	0.849	0.936	0.905	0.869	61	0.886	0.802	1.055	1.061
12	0.764	0.805	1.006	1.165	62	1.012	1.152	1.265	1.275
13	0.880	0.819	1.059	1.186	63	0.420	0.179	0.495	0.537
14	0.783	0.648	0.999	1.092	64	0.990	0.808	1.017	1.067
15	0.869	0.986	0.915	0.955	65	0.986	0.815	0.971	1.100
16	0.944	0.962	1.108	1.152	66	1.091	1.374	1.686	1.406
17	0.771	0.829	1.086	1.202	67	1.035	1.103	1.337	1.308
18	0.818	0.928	0.980	0.902	68	0.939	1.168	1.184	1.117
19	0.701	0.519	0.900	1.058	69	1.078	1.125	1.333	1.406
20	0.857	0.654	0.894	1.021	70	0.987	0.747	1.045	1.127
21	0.860	0.737	1.102	1.053	71	1.031	1.021	1.137	1.057
22	0.937	0.937	1.043	1.061	72	1.018	1.262	1.034	1.133
23	0.855	0.955	1.185	1.194	73	NC	NC	NC	NC
24	0.726	0.821	1.008	1.016	74	0.970	0.818	0.920	1.033
25	0.960	1.030	1.015	1.191	75	0.498	0.353	0.535	0.654
26	0.883	0.794	1.049	1.143	76	0.771	0.753	0.908	1.073
27	1.010	1.082	1.051	1.038	77	0.724	0.532	0.840	0.812
28	0.897	0.845	0.893	0.992	78	0.936	0.969	0.994	1.013
29	0.906	1.086	1.020	1.104	79	0.975	0.773	0.935	0.995
30	0.813	0.911	1.125	1.002	80	NC	NC	NC	NC
31	0.903	0.623	1.242	1.183	81	NC	NC	NC	NC
32	0.816	1.015	1.003	1.056	82	NC	NC	NC	NC
33	0.955	0.979	0.974	0.956	83	0.959	1.054	1.103	1.036
34	1.012	1.260	0.913	1.008	84	0.992	1.200	1.229	1.162
35	0.784	0.607	1.076	1.222	85	0.900	0.880	1.020	1.101
36	0.930	1.284	1.092	1.038	86	0.749	0.533	0.781	0.843
37	0.835	1.107	0.954	1.071	87	NC	NC	NC	NC
38	0.965	0.696	1.289	1.408	88	1.024	1.014	1.154	1.110
39	0.849	0.955	0.832	0.822	89	0.735	0.491	0.635	0.679
40	0.886	0.855	1.013	1.145	90	1.048	1.009	1.191	1.175
41	0.809	0.806	1.256	1.086	91	NC	NC	NC	NC
42	1.027	1.250	1.069	1.036	92	0.996	1.090	0.980	1.092
43	1.010	0.776	1.191	1.187	93	0.972	0.708	0.986	1.081
44	0.723	0.837	0.873	1.083	94	NC	NC	NC	NC
45	0.951	0.633	1.230	1.308	95	0.998	1.347	0.901	0.954
46	0.971	1.152	0.955	0.932	96	0.944	1.837	1.399	1.234
47	0.976	1.005	1.042	1.108	97	1.127	1.494	1.440	1.700
48	0.821	0.868	0.997	1.087	98	0.897	0.787	0.882	1.025
49	0.990	1.048	1.258	1.274	99	NC	NC	NC	NC
50	0.955	0.711	1.011	1.099	100	0.935	1.300	1.130	0.955

NC : Not Considered

Table A.4.33 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Base Shear for Frame 'F5S7B'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	1.088	1.088	1.045	1.270	51	0.936	0.707	0.944	0.970
2	1.116	1.116	1.735	1.864	52	1.071	1.073	1.072	1.072
3	0.956	0.925	1.146	1.189	53	0.981	0.960	1.089	1.105
4	1.000	0.999	0.997	0.909	54	0.862	0.806	0.863	0.891
5	0.826	0.888	0.971	0.987	55	0.912	0.851	0.965	0.967
6	0.802	0.833	0.634	0.599	56	1.009	1.008	1.010	1.011
7	0.743	0.772	0.973	1.064	57	0.880	1.087	1.042	0.981
8	0.792	0.884	1.155	1.115	58	NC	NC	NC	NC
9	0.985	1.407	1.089	1.019	59	0.898	0.891	0.899	0.903
10	1.050	1.382	1.028	0.868	60	0.922	0.787	1.015	1.120
11	0.853	0.931	0.903	0.871	61	0.781	0.721	0.892	0.895
12	0.781	0.819	1.005	1.139	62	1.023	1.028	1.033	1.033
13	0.868	0.819	1.003	1.088	63	0.889	0.686	0.896	0.898
14	0.783	0.674	0.941	0.996	64	0.988	0.920	0.994	1.007
15	0.879	0.983	0.920	0.955	65	1.102	0.944	1.089	1.203
16	0.927	0.943	1.073	1.112	66	1.027	1.052	1.061	1.053
17	0.679	0.726	0.930	1.016	67	0.971	0.973	0.982	0.981
18	0.868	0.976	1.026	0.951	68	0.986	1.047	1.049	1.036
19	0.770	0.606	0.921	1.017	69	0.961	0.964	0.968	0.963
20	0.845	0.687	0.870	0.944	70	0.938	0.927	0.938	0.942
21	0.896	0.792	1.077	1.044	71	1.134	1.130	1.162	1.141
22	0.957	0.957	1.022	1.033	72	1.000	1.127	1.010	1.070
23	0.907	1.004	1.218	1.226	73	NC	NC	NC	NC
24	0.738	0.823	0.989	0.996	74	1.030	0.998	1.020	1.036
25	0.929	0.986	0.974	1.105	75	0.973	0.960	0.976	0.971
26	0.920	0.861	0.988	1.010	76	0.899	0.887	0.994	1.061
27	1.120	1.171	1.150	1.141	77	0.954	0.947	0.969	0.968
28	0.858	0.818	0.855	0.926	78	1.035	1.036	1.036	1.038
29	0.950	1.063	1.022	1.074	79	1.049	1.036	1.046	1.050
30	0.864	0.955	1.152	1.039	80	NC	NC	NC	NC
31	0.932	0.754	1.008	1.000	81	NC	NC	NC	NC
32	0.863	0.991	0.984	1.016	82	NC	NC	NC	NC
33	1.058	1.079	1.074	1.058	83	1.016	1.019	1.023	1.017
34	0.965	1.149	0.880	0.961	84	0.886	0.933	0.938	0.925
35	0.848	0.675	1.091	1.199	85	0.979	0.978	0.982	0.985
36	0.967	1.199	1.084	1.047	86	0.950	0.838	0.958	0.971
37	0.907	0.967	0.940	0.962	87	0.958	0.950	0.957	0.953
38	0.997	0.795	1.153	1.180	88	0.943	0.942	0.948	0.946
39	1.122	1.249	1.102	1.089	89	1.068	1.026	1.061	1.064
40	0.929	0.906	1.009	1.088	90	0.966	0.964	0.972	0.971
41	0.939	0.937	1.040	1.017	91	NC	NC	NC	NC
42	1.135	1.283	1.166	1.142	92	0.920	0.934	0.917	0.934
43	0.979	0.926	0.991	0.991	93	0.923	0.920	0.923	0.926
44	0.830	0.911	0.935	1.045	94	NC	NC	NC	NC
45	0.948	0.768	1.002	1.012	95	0.945	0.949	0.942	0.945
46	1.243	1.444	1.226	1.198	96	0.947	0.973	0.971	0.966
47	0.944	0.967	0.996	1.046	97	1.006	1.018	1.016	1.023
48	0.806	0.843	0.940	1.001	98	0.944	0.933	0.944	0.949
49	1.051	1.092	1.222	1.232	99	NC	NC	NC	NC
50	0.998	0.934	1.007	1.010	100	0.877	0.881	0.885	0.878

NC : Not Considered

Table A.4.34 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Top Displacement for Frame 'F5S7B'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	0.960	1.165	51	0.652	1.024	1.121
2	1.000	1.560	1.680	52	1.067	1.029	1.027
3	0.963	1.229	1.281	53	0.977	1.126	1.145
4	0.999	0.997	0.899	54	0.900	1.004	1.080
5	1.087	1.203	1.225	55	0.915	1.082	1.084
6	1.043	0.765	0.718	56	0.945	1.014	1.030
7	1.044	1.344	1.482	57	1.293	1.225	1.137
8	1.128	1.510	1.453	58	NC	NC	NC
9	1.535	1.124	1.041	59	0.782	1.008	1.074
10	1.370	0.977	0.813	60	0.826	1.132	1.303
11	1.101	1.065	1.024	61	0.911	1.178	1.184
12	1.053	1.315	1.512	62	1.138	1.246	1.256
13	0.935	1.191	1.321	63	0.465	1.175	1.279
14	0.839	1.255	1.358	64	0.839	1.025	1.070
15	1.135	1.053	1.099	65	0.837	0.986	1.106
16	1.018	1.172	1.219	66	1.239	1.517	1.266
17	1.076	1.408	1.553	67	1.065	1.291	1.263
18	1.135	1.198	1.103	68	1.212	1.226	1.165
19	0.757	1.258	1.451	69	1.043	1.236	1.296
20	0.776	1.039	1.166	70	0.760	1.059	1.144
21	0.867	1.259	1.208	71	0.992	1.091	1.022
22	1.000	1.098	1.115	72	1.212	1.014	1.102
23	1.117	1.379	1.390	73	NC	NC	NC
24	1.130	1.386	1.397	74	0.862	0.954	1.062
25	1.069	1.054	1.221	75	0.713	1.077	1.300
26	0.908	1.163	1.254	76	0.980	1.158	1.339
27	1.063	1.036	1.025	77	0.750	1.153	1.115
28	0.945	0.996	1.099	78	1.036	1.062	1.082
29	1.173	1.108	1.191	79	0.797	0.959	1.020
30	1.121	1.382	1.232	80	NC	NC	NC
31	0.720	1.323	1.268	81	NC	NC	NC
32	1.214	1.200	1.258	82	NC	NC	NC
33	1.023	1.018	1.001	83	1.099	1.152	1.079
34	1.224	0.904	0.996	84	1.182	1.207	1.149
35	0.779	1.341	1.510	85	0.979	1.131	1.220
36	1.336	1.158	1.107	86	0.742	1.038	1.109
37	1.281	1.125	1.245	87	NC	NC	NC
38	0.744	1.293	1.397	88	0.990	1.130	1.085
39	1.124	0.981	0.968	89	0.684	0.865	0.923
40	0.968	1.124	1.255	90	0.963	1.134	1.119
41	0.997	1.474	1.294	91	NC	NC	NC
42	1.190	1.036	1.008	92	1.081	0.986	1.083
43	0.794	1.172	1.168	93	0.739	1.013	1.103
44	1.137	1.180	1.429	94	NC	NC	NC
45	0.699	1.253	1.325	95	1.341	0.902	0.955
46	1.180	0.985	0.961	96	1.907	1.463	1.293
47	1.027	1.062	1.124	97	1.320	1.273	1.501
48	1.053	1.202	1.301	98	0.883	0.985	1.142
49	1.052	1.236	1.251	99	NC	NC	NC
50	0.772	1.054	1.144	100	1.379	1.210	1.021

NC : Not Considered

Table A.4.35 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Inter-story Drift Ratio for Frame 'F5S7B'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	0.960	1.166	51	0.618	1.028	1.139
2	1.000	1.557	1.676	52	1.068	1.030	1.027
3	0.963	1.230	1.282	53	0.977	1.135	1.156
4	0.999	0.997	0.898	54	0.888	1.005	1.093
5	1.087	1.204	1.226	55	0.908	1.094	1.096
6	1.044	0.765	0.717	56	0.946	1.013	1.029
7	1.044	1.346	1.484	57	1.317	1.242	1.146
8	1.129	1.512	1.455	58	NC	NC	NC
9	1.587	1.136	1.044	59	0.780	1.007	1.072
10	1.403	0.977	0.812	60	0.816	1.147	1.345
11	1.102	1.066	1.024	61	0.905	1.190	1.197
12	1.053	1.316	1.525	62	1.138	1.249	1.259
13	0.930	1.204	1.348	63	0.427	1.178	1.279
14	0.828	1.276	1.396	64	0.817	1.027	1.078
15	1.135	1.053	1.099	65	0.826	0.985	1.116
16	1.018	1.173	1.220	66	1.260	1.546	1.289
17	1.076	1.409	1.560	67	1.065	1.291	1.263
18	1.135	1.198	1.104	68	1.244	1.261	1.190
19	0.741	1.284	1.509	69	1.044	1.236	1.304
20	0.763	1.044	1.192	70	0.757	1.059	1.142
21	0.858	1.282	1.225	71	0.991	1.103	1.025
22	1.000	1.113	1.133	72	1.240	1.016	1.113
23	1.117	1.386	1.397	73	NC	NC	NC
24	1.131	1.388	1.398	74	0.843	0.948	1.066
25	1.074	1.058	1.241	75	0.710	1.074	1.313
26	0.899	1.188	1.295	76	0.977	1.178	1.393
27	1.071	1.040	1.028	77	0.734	1.159	1.121
28	0.942	0.996	1.106	78	1.036	1.062	1.082
29	1.198	1.125	1.218	79	0.793	0.959	1.020
30	1.121	1.384	1.233	80	NC	NC	NC
31	0.690	1.376	1.310	81	NC	NC	NC
32	1.244	1.229	1.295	82	NC	NC	NC
33	1.024	1.019	1.001	83	1.099	1.150	1.080
34	1.244	0.902	0.995	84	1.209	1.238	1.171
35	0.774	1.372	1.557	85	0.978	1.133	1.223
36	1.381	1.174	1.116	86	0.712	1.043	1.127
37	1.327	1.143	1.284	87	NC	NC	NC
38	0.722	1.336	1.460	88	0.990	1.127	1.084
39	1.125	0.981	0.968	89	0.668	0.864	0.923
40	0.965	1.143	1.292	90	0.963	1.136	1.121
41	0.996	1.552	1.342	91	NC	NC	NC
42	1.218	1.041	1.009	92	1.095	0.983	1.097
43	0.768	1.180	1.175	93	0.728	1.014	1.111
44	1.157	1.207	1.498	94	NC	NC	NC
45	0.666	1.294	1.376	95	1.350	0.902	0.956
46	1.187	0.984	0.960	96	1.945	1.482	1.307
47	1.029	1.067	1.134	97	1.326	1.278	1.508
48	1.058	1.216	1.325	98	0.877	0.984	1.143
49	1.058	1.270	1.287	99	NC	NC	NC
50	0.744	1.058	1.151	100	1.391	1.210	1.022

NC : Not Considered

Table A.4.36 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Base Shear for Frame 'F5S7B'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	0.960	1.166	51	0.756	1.009	1.036
2	1.000	1.555	1.670	52	1.002	1.001	1.001
3	0.968	1.199	1.244	53	0.979	1.110	1.127
4	0.999	0.997	0.909	54	0.935	1.002	1.034
5	1.076	1.176	1.195	55	0.933	1.058	1.060
6	1.038	0.790	0.747	56	0.999	1.001	1.002
7	1.040	1.309	1.432	57	1.236	1.184	1.115
8	1.116	1.459	1.408	58	NC	NC	NC
9	1.428	1.106	1.035	59	0.992	1.001	1.006
10	1.316	0.979	0.826	60	0.853	1.100	1.214
11	1.092	1.059	1.021	61	0.923	1.142	1.147
12	1.049	1.287	1.458	62	1.005	1.010	1.010
13	0.944	1.156	1.253	63	0.771	1.007	1.011
14	0.860	1.201	1.271	64	0.931	1.006	1.020
15	1.118	1.046	1.087	65	0.856	0.988	1.091
16	1.017	1.158	1.200	66	1.024	1.033	1.025
17	1.069	1.370	1.497	67	1.002	1.012	1.010
18	1.124	1.181	1.095	68	1.061	1.064	1.050
19	0.788	1.197	1.322	69	1.003	1.007	1.002
20	0.813	1.029	1.117	70	0.989	1.001	1.004
21	0.885	1.202	1.165	71	0.997	1.025	1.007
22	1.000	1.068	1.080	72	1.127	1.010	1.070
23	1.107	1.343	1.352	73	NC	NC	NC
24	1.116	1.341	1.350	74	0.969	0.990	1.006
25	1.061	1.048	1.190	75	0.987	1.004	0.999
26	0.936	1.074	1.098	76	0.986	1.105	1.180
27	1.046	1.026	1.018	77	0.993	1.016	1.014
28	0.954	0.997	1.080	78	1.002	1.001	1.003
29	1.119	1.075	1.130	79	0.988	0.997	1.001
30	1.106	1.333	1.203	80	NC	NC	NC
31	0.809	1.081	1.073	81	NC	NC	NC
32	1.148	1.140	1.177	82	NC	NC	NC
33	1.020	1.016	1.001	83	1.003	1.007	1.001
34	1.191	0.912	0.996	84	1.053	1.059	1.045
35	0.796	1.286	1.413	85	0.999	1.003	1.006
36	1.241	1.122	1.084	86	0.883	1.009	1.022
37	1.067	1.037	1.061	87	NC	NC	NC
38	0.798	1.157	1.184	88	0.999	1.006	1.003
39	1.114	0.982	0.971	89	0.961	0.994	0.996
40	0.976	1.086	1.172	90	0.998	1.006	1.005
41	0.999	1.108	1.083	91	NC	NC	NC
42	1.130	1.026	1.006	92	1.015	0.997	1.016
43	0.946	1.012	1.012	93	0.997	1.000	1.003
44	1.097	1.126	1.259	94	NC	NC	NC
45	0.810	1.057	1.068	95	1.004	0.997	1.000
46	1.161	0.986	0.964	96	1.027	1.026	1.020
47	1.024	1.055	1.108	97	1.011	1.010	1.017
48	1.046	1.167	1.242	98	0.989	0.999	1.005
49	1.039	1.163	1.173	99	NC	NC	NC
50	0.936	1.009	1.012	100	1.005	1.010	1.002

NC : Not Considered

Table A.4.37 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Top Displacement for Frame 'F8S3B'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	0.981	0.981	1.179	1.191	51	1.030	0.846	1.068	1.085
2	0.996	0.996	1.332	1.352	52	0.817	0.607	0.841	0.888
3	0.971	0.969	1.015	1.018	53	0.933	0.881	1.086	1.093
4	0.992	0.992	1.034	1.027	54	1.022	0.865	0.934	0.944
5	0.922	0.921	1.411	1.427	55	0.994	0.843	1.028	1.071
6	0.781	0.788	1.100	1.150	56	0.875	0.769	1.002	1.027
7	0.913	0.934	0.931	0.926	57	0.878	0.803	1.077	1.090
8	0.808	0.947	1.005	0.973	58	0.986	0.713	0.977	1.045
9	0.814	0.847	0.954	0.969	59	1.018	0.957	1.119	1.135
10	0.895	0.881	0.834	0.808	60	0.931	1.116	1.002	1.001
11	0.962	0.904	1.100	1.117	61	0.980	1.084	0.992	0.978
12	0.725	0.623	0.977	1.020	62	0.755	0.806	0.878	0.875
13	0.985	1.329	0.976	0.948	63	0.916	1.212	1.069	1.048
14	0.809	0.779	0.977	1.014	64	0.914	0.675	0.839	0.857
15	0.734	0.940	1.239	1.294	65	0.986	0.926	1.129	1.138
16	0.908	0.757	1.063	1.088	66	0.797	0.638	0.894	0.916
17	0.816	0.773	1.021	1.028	67	0.926	0.977	1.066	1.058
18	0.842	0.955	0.932	0.922	68	0.990	0.736	1.104	1.133
19	0.813	0.874	0.806	0.841	69	0.961	0.963	1.016	1.034
20	1.038	0.803	0.966	0.981	70	1.014	1.043	1.169	1.139
21	0.827	0.973	0.929	0.920	71	0.782	0.912	0.919	0.940
22	1.003	0.910	1.148	1.150	72	0.919	0.892	1.061	1.075
23	0.913	0.892	1.127	1.136	73	0.958	0.776	1.033	1.051
24	0.844	0.932	1.003	1.053	74	1.004	1.006	1.177	1.162
25	0.877	0.743	0.964	0.980	75	1.198	1.247	1.636	1.554
26	0.837	0.959	0.996	0.992	76	0.924	1.072	1.081	1.072
27	0.892	0.869	1.001	1.010	77	NC	NC	NC	NC
28	0.976	0.889	1.073	1.080	78	0.892	0.838	1.026	1.050
29	0.913	0.664	0.986	0.997	79	0.883	0.929	0.892	0.897
30	0.971	0.971	0.821	0.822	80	0.969	1.137	1.037	1.047
31	1.031	1.102	1.224	1.202	81	1.116	1.002	1.261	1.279
32	0.935	0.715	1.065	1.045	82	NC	NC	NC	NC
33	0.969	0.956	0.921	0.946	83	0.872	0.915	0.888	0.886
34	0.891	0.990	0.953	0.952	84	0.857	0.773	1.008	0.994
35	0.812	0.583	0.983	1.009	85	1.056	1.122	1.194	1.161
36	0.894	0.872	0.945	0.948	86	0.981	1.047	0.999	0.996
37	0.816	0.705	0.918	0.944	87	1.030	0.975	1.015	1.019
38	0.908	0.911	1.024	1.028	88	0.989	0.773	0.965	0.994
39	0.972	1.050	1.084	1.072	89	1.181	0.967	1.195	1.218
40	0.921	0.711	0.953	0.976	90	0.840	0.957	0.941	0.943
41	0.935	0.795	1.050	1.040	91	0.888	0.990	0.871	0.861
42	0.800	0.767	0.902	0.894	92	1.000	0.993	1.026	1.032
43	0.906	0.709	0.911	0.929	93	1.023	1.215	1.047	1.067
44	0.989	0.913	1.092	1.087	94	0.934	0.761	1.163	1.199
45	0.988	0.874	1.075	1.106	95	1.205	1.381	1.236	1.202
46	0.889	0.774	0.953	0.965	96	0.924	1.022	0.936	0.959
47	0.849	0.709	0.992	1.011	97	0.635	0.794	0.744	0.741
48	0.873	0.713	0.922	0.946	98	0.579	0.606	0.531	0.560
49	0.938	0.823	0.928	0.938	99	0.999	1.010	0.992	0.991
50	0.951	0.988	1.037	1.023	100	NC	NC	NC	NC

NC : Not Considered

Table A.4.38 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Inter-story Drift Ratio for Frame 'F8S3B'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	0.931	0.931	1.115	1.127	51	1.013	0.811	1.055	1.073
2	0.785	0.786	1.044	1.059	52	0.659	0.476	0.683	0.729
3	0.922	0.920	0.964	0.967	53	0.919	0.869	1.068	1.075
4	0.751	0.751	0.782	0.778	54	1.049	0.859	0.944	0.955
5	0.829	0.829	1.277	1.292	55	0.924	0.759	0.961	1.007
6	0.507	0.511	0.717	0.750	56	0.755	0.653	0.874	0.896
7	0.752	0.769	0.767	0.763	57	0.866	0.787	1.116	1.131
8	0.804	0.942	0.998	0.967	58	0.899	0.621	0.890	0.956
9	0.792	0.824	0.927	0.942	59	1.058	1.004	1.146	1.160
10	0.740	0.729	0.690	0.668	60	0.851	1.018	0.916	0.915
11	0.993	0.933	1.135	1.153	61	1.005	1.136	1.021	1.003
12	0.732	0.629	0.984	1.028	62	0.686	0.731	0.800	0.797
13	0.839	1.130	0.832	0.808	63	0.787	1.073	0.936	0.917
14	0.796	0.766	0.958	0.994	64	0.950	0.680	0.867	0.887
15	0.713	0.913	1.202	1.256	65	0.894	0.840	1.027	1.036
16	0.912	0.762	1.067	1.091	66	0.576	0.452	0.663	0.683
17	0.795	0.754	0.991	0.997	67	0.792	0.844	0.931	0.924
18	0.764	0.866	0.845	0.836	68	0.981	0.706	1.098	1.127
19	0.828	0.887	0.821	0.855	69	0.893	0.895	0.947	0.965
20	1.054	0.823	0.989	1.003	70	1.037	1.067	1.200	1.169
21	0.807	0.949	0.906	0.898	71	0.627	0.730	0.736	0.753
22	0.979	0.870	1.157	1.158	72	0.798	0.772	0.935	0.948
23	0.917	0.896	1.130	1.139	73	0.932	0.767	0.995	1.010
24	0.830	0.916	0.985	1.034	74	0.666	0.668	0.814	0.801
25	0.815	0.691	0.895	0.908	75	0.927	0.966	1.246	1.190
26	0.708	0.839	0.879	0.875	76	0.784	0.941	0.951	0.942
27	0.902	0.879	1.011	1.020	77	NC	NC	NC	NC
28	0.929	0.844	1.017	1.023	78	0.824	0.768	0.964	0.988
29	0.869	0.613	0.942	0.952	79	0.639	0.671	0.645	0.649
30	0.330	0.330	0.280	0.280	80	0.743	0.874	0.798	0.805
31	1.021	1.112	1.264	1.237	81	0.757	0.691	0.840	0.850
32	0.796	0.576	0.923	0.903	82	NC	NC	NC	NC
33	0.494	0.487	0.469	0.482	83	0.574	0.607	0.585	0.584
34	0.807	0.896	0.863	0.862	84	0.597	0.539	0.706	0.695
35	0.752	0.541	0.909	0.933	85	0.771	0.826	0.887	0.859
36	0.837	0.817	0.884	0.887	86	0.865	0.930	0.882	0.880
37	0.762	0.639	0.874	0.901	87	0.929	0.882	0.916	0.920
38	0.782	0.785	0.885	0.888	88	1.023	0.791	0.998	1.028
39	0.328	0.355	0.366	0.362	89	1.070	0.869	1.082	1.102
40	0.949	0.740	0.979	1.001	90	0.808	0.941	0.923	0.925
41	0.839	0.690	0.960	0.950	91	0.707	0.780	0.694	0.686
42	0.410	0.394	0.462	0.458	92	0.901	0.893	0.927	0.933
43	0.817	0.606	0.823	0.841	93	0.733	0.889	0.753	0.769
44	0.907	0.829	1.015	1.009	94	0.885	0.720	1.073	1.102
45	1.005	0.874	1.104	1.139	95	1.110	1.245	1.134	1.107
46	0.544	0.475	0.584	0.591	96	0.646	0.733	0.656	0.675
47	0.840	0.703	0.999	1.025	97	0.593	0.767	0.714	0.711
48	0.873	0.708	0.938	0.969	98	0.531	0.558	0.482	0.512
49	0.912	0.802	0.903	0.912	99	0.765	0.774	0.759	0.758
50	0.941	0.982	1.037	1.022	100	NC	NC	NC	NC

NC : Not Considered

Table A.4.39 Comparison Results of Approximations with respect to 'EXACT' Values of Maximum Base Shear for Frame 'F8S3B'

EQ	MULTI	ATC	FEMA	75%Vy	EQ	MULTI	ATC	FEMA	75%Vy
1	0.976	0.976	1.178	1.191	51	0.782	0.746	0.789	0.792
2	0.822	0.822	1.110	1.127	52	0.709	0.576	0.715	0.727
3	1.124	1.123	1.169	1.172	53	0.759	0.720	0.873	0.878
4	0.636	0.636	0.663	0.659	54	0.887	0.847	0.867	0.869
5	0.896	0.896	1.327	1.341	55	0.931	0.890	0.938	0.948
6	0.633	0.638	0.861	0.896	56	0.879	0.853	0.906	0.910
7	0.897	0.915	0.913	0.909	57	0.836	0.786	0.894	0.897
8	0.756	0.875	0.923	0.897	58	0.957	0.885	0.955	0.969
9	0.786	0.816	0.911	0.925	59	0.899	0.895	0.906	0.907
10	1.083	1.067	1.016	0.988	60	0.975	1.154	1.044	1.043
11	0.777	0.735	0.876	0.888	61	0.903	0.931	0.906	0.902
12	0.701	0.609	0.925	0.964	62	0.736	0.780	0.830	0.829
13	1.295	1.706	1.284	1.251	63	0.811	0.865	0.841	0.837
14	0.724	0.698	0.860	0.886	64	0.834	0.778	0.819	0.822
15	0.811	1.012	1.296	1.348	65	0.708	0.667	0.784	0.788
16	0.694	0.587	0.803	0.820	66	0.792	0.681	0.820	0.826
17	0.961	0.914	1.179	1.186	67	0.738	0.748	0.764	0.762
18	0.754	0.844	0.825	0.817	68	0.802	0.749	0.820	0.824
19	0.846	0.898	0.839	0.870	69	0.829	0.829	0.839	0.842
20	0.888	0.852	0.880	0.882	70	0.832	0.837	0.856	0.852
21	0.797	0.928	0.889	0.881	71	0.700	0.808	0.814	0.831
22	0.826	0.785	0.861	0.861	72	0.945	0.938	0.977	0.979
23	0.973	0.953	1.181	1.189	73	0.992	0.963	1.000	1.002
24	0.764	0.835	0.892	0.933	74	0.897	0.897	0.947	0.943
25	0.985	0.844	1.076	1.090	75	0.942	0.950	0.989	0.983
26	0.887	0.927	0.937	0.936	76	0.923	0.988	0.991	0.989
27	0.758	0.739	0.844	0.851	77	NC	NC	NC	NC
28	0.911	0.895	0.925	0.926	78	0.738	0.727	0.762	0.766
29	0.941	0.875	0.955	0.957	79	0.997	1.039	1.005	1.010
30	0.432	0.432	0.368	0.368	80	0.783	0.807	0.794	0.795
31	0.845	0.867	0.895	0.890	81	0.827	0.821	0.834	0.835
32	0.959	0.889	0.989	0.985	82	NC	NC	NC	NC
33	0.717	0.708	0.685	0.702	83	0.923	0.934	0.927	0.926
34	0.908	1.001	0.966	0.966	84	0.787	0.715	0.890	0.883
35	0.684	0.504	0.817	0.837	85	0.744	0.755	0.766	0.761
36	0.838	0.819	0.883	0.885	86	1.067	1.083	1.071	1.071
37	0.863	0.827	0.888	0.894	87	0.790	0.783	0.788	0.789
38	0.886	0.889	0.971	0.973	88	0.819	0.778	0.815	0.820
39	0.440	0.472	0.485	0.481	89	0.846	0.813	0.848	0.851
40	0.874	0.837	0.878	0.880	90	0.742	0.767	0.764	0.764
41	1.077	1.028	1.108	1.105	91	0.839	0.850	0.836	0.834
42	0.466	0.449	0.520	0.515	92	0.784	0.782	0.789	0.789
43	0.982	0.914	0.983	0.988	93	0.918	0.956	0.923	0.927
44	0.881	0.864	0.901	0.900	94	0.735	0.708	0.753	0.756
45	0.912	0.886	0.930	0.936	95	0.905	0.916	0.907	0.905
46	0.710	0.627	0.756	0.765	96	0.820	0.854	0.826	0.836
47	0.773	0.655	0.854	0.859	97	0.666	0.704	0.694	0.693
48	0.713	0.609	0.727	0.733	98	0.680	0.687	0.666	0.675
49	0.787	0.699	0.781	0.788	99	0.761	0.763	0.760	0.760
50	0.955	0.964	0.975	0.972	100	NC	NC	NC	NC

NC : Not Considered

Table A.4.40 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Top Displacement for Frame 'F8S3B'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	1.202	1.214	51	0.822	1.037	1.053
2	1.000	1.338	1.358	52	0.742	1.029	1.087
3	0.999	1.046	1.048	53	0.945	1.164	1.172
4	1.000	1.042	1.035	54	0.846	0.914	0.923
5	1.000	1.531	1.548	55	0.848	1.034	1.077
6	1.009	1.408	1.472	56	0.879	1.145	1.174
7	1.023	1.019	1.015	57	0.915	1.227	1.241
8	1.172	1.243	1.204	58	0.723	0.991	1.060
9	1.041	1.172	1.191	59	0.940	1.099	1.115
10	0.984	0.932	0.902	60	1.199	1.077	1.076
11	0.940	1.143	1.161	61	1.106	1.012	0.998
12	0.859	1.347	1.407	62	1.068	1.163	1.159
13	1.350	0.991	0.963	63	1.323	1.167	1.144
14	0.962	1.207	1.253	64	0.738	0.918	0.937
15	1.282	1.689	1.764	65	0.939	1.145	1.153
16	0.834	1.171	1.198	66	0.801	1.122	1.150
17	0.948	1.251	1.260	67	1.056	1.151	1.143
18	1.134	1.107	1.095	68	0.743	1.115	1.145
19	1.075	0.991	1.034	69	1.002	1.057	1.077
20	0.773	0.931	0.946	70	1.028	1.153	1.123
21	1.177	1.123	1.113	71	1.166	1.175	1.202
22	0.908	1.145	1.146	72	0.971	1.155	1.170
23	0.977	1.235	1.244	73	0.810	1.078	1.097
24	1.104	1.188	1.248	74	1.002	1.173	1.157
25	0.847	1.100	1.117	75	1.041	1.365	1.297
26	1.145	1.190	1.185	76	1.159	1.169	1.160
27	0.974	1.122	1.132	77	NC	NC	NC
28	0.911	1.099	1.106	78	0.939	1.150	1.177
29	0.727	1.081	1.092	79	1.053	1.011	1.016
30	1.000	0.845	0.846	80	1.174	1.071	1.080
31	1.068	1.186	1.165	81	0.898	1.130	1.145
32	0.765	1.140	1.119	82	NC	NC	NC
33	0.986	0.950	0.976	83	1.049	1.017	1.016
34	1.110	1.069	1.068	84	0.903	1.176	1.160
35	0.718	1.210	1.242	85	1.062	1.131	1.099
36	0.976	1.057	1.061	86	1.067	1.018	1.016
37	0.864	1.125	1.157	87	0.947	0.986	0.990
38	1.004	1.128	1.132	88	0.782	0.976	1.005
39	1.081	1.116	1.103	89	0.818	1.012	1.031
40	0.772	1.035	1.060	90	1.140	1.120	1.122
41	0.851	1.123	1.113	91	1.114	0.980	0.969
42	0.959	1.128	1.118	92	0.993	1.026	1.032
43	0.783	1.006	1.025	93	1.188	1.024	1.043
44	0.924	1.105	1.100	94	0.815	1.245	1.284
45	0.885	1.088	1.120	95	1.146	1.026	0.998
46	0.871	1.072	1.086	96	1.106	1.013	1.038
47	0.835	1.168	1.191	97	1.249	1.172	1.167
48	0.817	1.057	1.084	98	1.046	0.916	0.967
49	0.878	0.990	1.001	99	1.011	0.993	0.992
50	1.038	1.090	1.076	100	NC	NC	NC

NC : Not Considered

Table A.4.41 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Inter-story Drift Ratio for Frame 'F8S3B'

EQ	ATC	FEMA	75%Vy	EQ	ATC	FEMA	75%Vy
1	1.000	1.198	1.210	51	0.801	1.042	1.059
2	1.000	1.329	1.349	52	0.723	1.036	1.107
3	0.999	1.046	1.049	53	0.945	1.162	1.169
4	1.000	1.042	1.035	54	0.819	0.900	0.910
5	1.000	1.540	1.558	55	0.821	1.039	1.089
6	1.009	1.415	1.480	56	0.865	1.157	1.187
7	1.023	1.019	1.015	57	0.909	1.289	1.307
8	1.170	1.241	1.203	58	0.692	0.990	1.064
9	1.041	1.171	1.190	59	0.949	1.083	1.096
10	0.984	0.932	0.903	60	1.197	1.076	1.076
11	0.940	1.143	1.161	61	1.130	1.015	0.998
12	0.860	1.345	1.405	62	1.065	1.166	1.161
13	1.347	0.991	0.963	63	1.364	1.190	1.165
14	0.962	1.203	1.247	64	0.716	0.913	0.933
15	1.282	1.687	1.762	65	0.939	1.149	1.158
16	0.835	1.170	1.196	66	0.785	1.152	1.186
17	0.948	1.246	1.254	67	1.065	1.176	1.166
18	1.134	1.106	1.094	68	0.720	1.119	1.149
19	1.071	0.991	1.032	69	1.002	1.061	1.081
20	0.781	0.938	0.952	70	1.029	1.157	1.127
21	1.176	1.122	1.112	71	1.165	1.174	1.201
22	0.889	1.181	1.183	72	0.968	1.172	1.189
23	0.977	1.233	1.243	73	0.823	1.068	1.084
24	1.104	1.187	1.246	74	1.002	1.221	1.202
25	0.848	1.099	1.115	75	1.042	1.345	1.284
26	1.187	1.242	1.236	76	1.200	1.213	1.201
27	0.974	1.121	1.131	77	NC	NC	NC
28	0.908	1.095	1.101	78	0.931	1.169	1.198
29	0.705	1.083	1.095	79	1.050	1.010	1.015
30	1.000	0.847	0.849	80	1.176	1.073	1.083
31	1.089	1.238	1.212	81	0.913	1.110	1.123
32	0.723	1.159	1.135	82	NC	NC	NC
33	0.986	0.950	0.976	83	1.058	1.021	1.019
34	1.110	1.068	1.068	84	0.903	1.182	1.164
35	0.719	1.209	1.241	85	1.071	1.149	1.113
36	0.976	1.057	1.060	86	1.075	1.020	1.018
37	0.838	1.147	1.183	87	0.949	0.986	0.991
38	1.003	1.131	1.135	88	0.773	0.976	1.005
39	1.081	1.116	1.104	89	0.813	1.011	1.030
40	0.779	1.032	1.054	90	1.164	1.141	1.144
41	0.823	1.144	1.132	91	1.102	0.981	0.970
42	0.959	1.127	1.117	92	0.992	1.030	1.036
43	0.742	1.007	1.030	93	1.214	1.027	1.049
44	0.914	1.118	1.112	94	0.814	1.213	1.245
45	0.870	1.099	1.133	95	1.122	1.022	0.998
46	0.872	1.072	1.086	96	1.135	1.014	1.045
47	0.836	1.189	1.220	97	1.295	1.204	1.199
48	0.812	1.075	1.110	98	1.051	0.907	0.964
49	0.880	0.991	1.001	99	1.013	0.992	0.991
50	1.043	1.102	1.085	100	NC	NC	NC

NC : Not Considered

Table A.4.42 Comparison Results of Approximations with respect to 'MULTI' Values of Maximum Base Shear for Frame 'F8S3B'

EQ	ATC	FEMA	75%Vy
1	1.000	1.207	1.220
2	1.000	1.350	1.371
3	0.999	1.040	1.043
4	1.000	1.042	1.035
5	1.000	1.481	1.497
6	1.008	1.361	1.416
7	1.020	1.017	1.013
8	1.156	1.220	1.186
9	1.038	1.159	1.177
10	0.986	0.939	0.912
11	0.946	1.127	1.143
12	0.869	1.320	1.375
13	1.317	0.992	0.966
14	0.964	1.187	1.223
15	1.247	1.598	1.662
16	0.846	1.158	1.182
17	0.951	1.227	1.233
18	1.120	1.095	1.085
19	1.062	0.992	1.028
20	0.959	0.991	0.993
21	1.164	1.115	1.105
22	0.951	1.042	1.043
23	0.979	1.213	1.222
24	1.094	1.169	1.222
25	0.856	1.092	1.107
26	1.046	1.057	1.056
27	0.976	1.113	1.123
28	0.982	1.015	1.016
29	0.930	1.016	1.018
30	1.000	0.851	0.852
31	1.025	1.058	1.053
32	0.927	1.032	1.027
33	0.988	0.956	0.979
34	1.102	1.063	1.063
35	0.736	1.195	1.224
36	0.977	1.054	1.057
37	0.959	1.029	1.036
38	1.003	1.096	1.099
39	1.072	1.102	1.092
40	0.958	1.004	1.007
41	0.955	1.029	1.027
42	0.963	1.116	1.106
43	0.931	1.002	1.006
44	0.981	1.024	1.023
45	0.971	1.020	1.027
46	0.883	1.065	1.078
47	0.846	1.104	1.111
48	0.855	1.020	1.029
49	0.888	0.992	1.001
50	1.009	1.021	1.017
51	0.954	1.009	1.012
52	0.813	1.009	1.026
53	0.948	1.151	1.158
54	0.955	0.978	0.980
55	0.956	1.008	1.018
56	0.970	1.030	1.035
57	0.940	1.069	1.072
58	0.925	0.998	1.013
59	0.995	1.007	1.008
60	1.183	1.071	1.070
61	1.031	1.004	0.999
62	1.059	1.128	1.125
63	1.067	1.037	1.033
64	0.933	0.982	0.986
65	0.943	1.108	1.113
66	0.860	1.036	1.043
67	1.013	1.035	1.033
68	0.934	1.022	1.027
69	1.000	1.012	1.016
70	1.006	1.029	1.024
71	1.154	1.163	1.187
72	0.993	1.034	1.037
73	0.971	1.008	1.010
74	1.001	1.056	1.052
75	1.008	1.049	1.043
76	1.071	1.074	1.071
77	NC	NC	NC
78	0.985	1.033	1.038
79	1.043	1.009	1.013
80	1.031	1.014	1.016
81	0.992	1.009	1.010
82	NC	NC	NC
83	1.012	1.004	1.004
84	0.909	1.131	1.123
85	1.015	1.030	1.023
86	1.015	1.004	1.004
87	0.991	0.998	0.998
88	0.951	0.996	1.001
89	0.960	1.002	1.005
90	1.033	1.028	1.029
91	1.014	0.997	0.995
92	0.998	1.006	1.007
93	1.042	1.006	1.010
94	0.963	1.025	1.028
95	1.012	1.002	1.000
96	1.043	1.008	1.020
97	1.057	1.041	1.040
98	1.010	0.980	0.992
99	1.003	0.998	0.998
100	NC	NC	NC

NC : Not Considered

A.5 COMPARISON OF APPROXIMATE RESULTS (SCATTER GRAPHS)

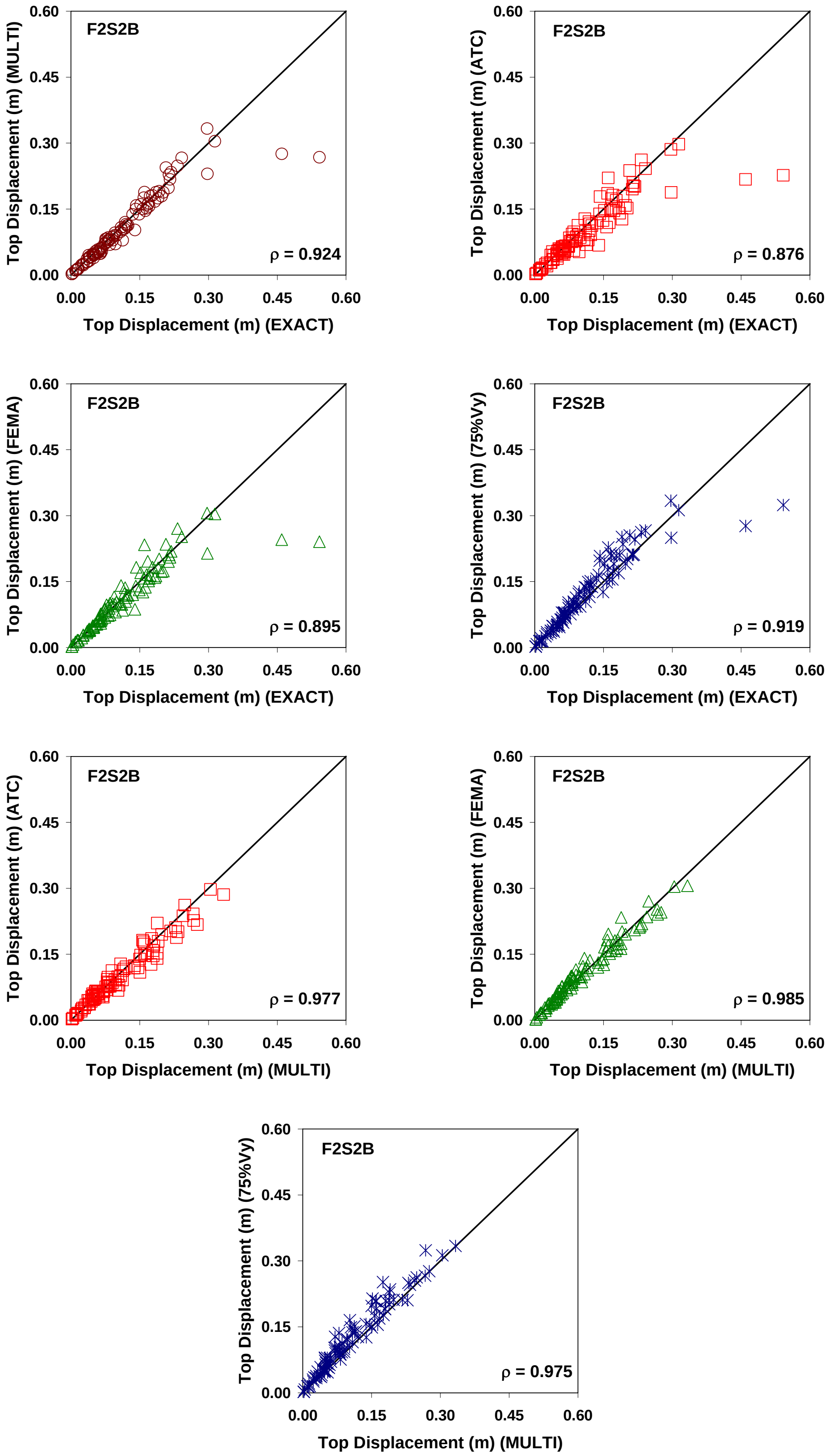


Figure A.5.1 Comparison of Approximate Results with respect to ‘EXACT’ and ‘MULTI’ Values of Maximum Top Displacement for Frame ‘F2S2B’

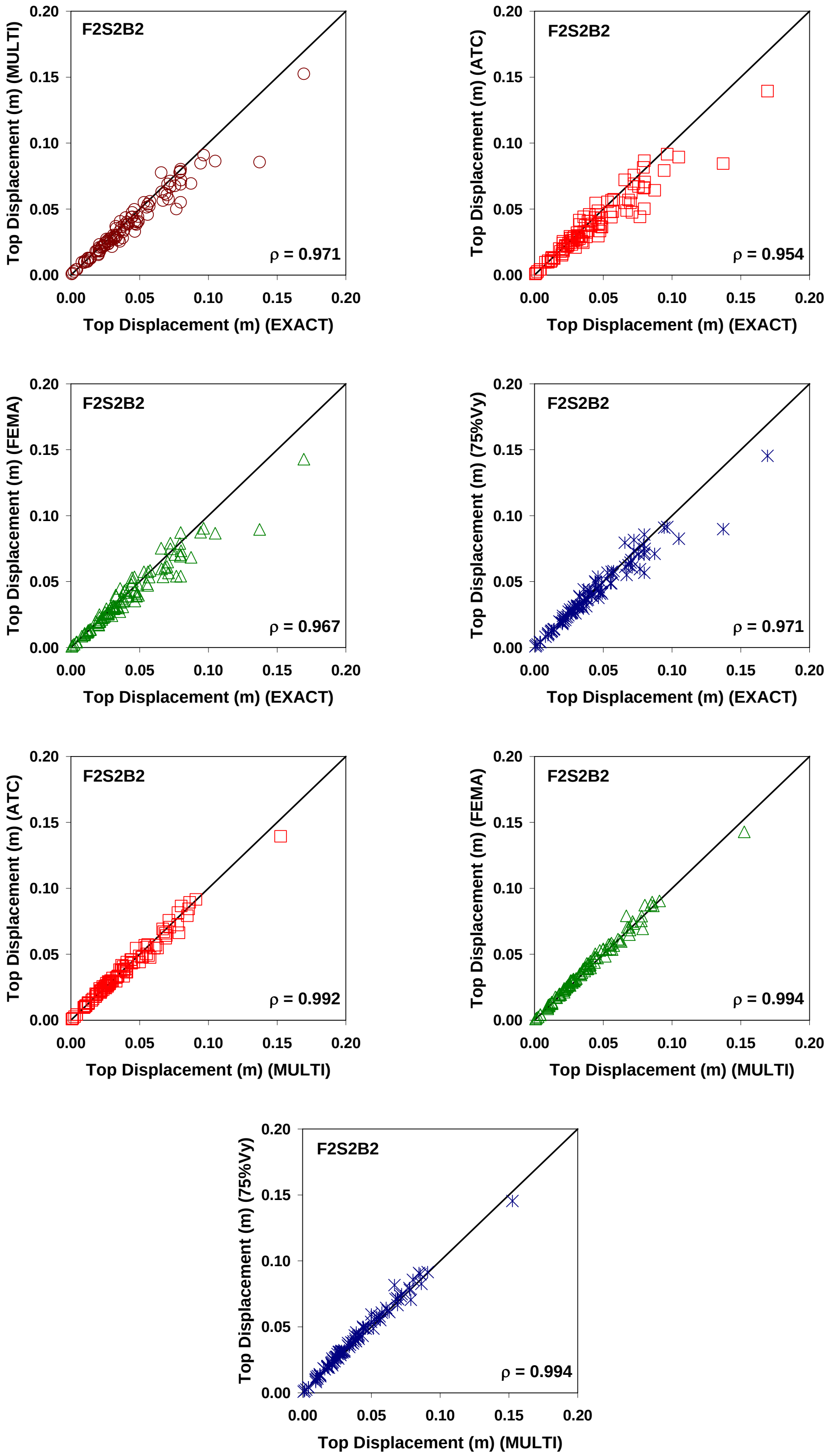


Figure A.5.2 Comparison of Approximate Results with respect to ‘EXACT’ and ‘MULTI’ Values of Maximum Top Displacement for Frame ‘F2S2B2’

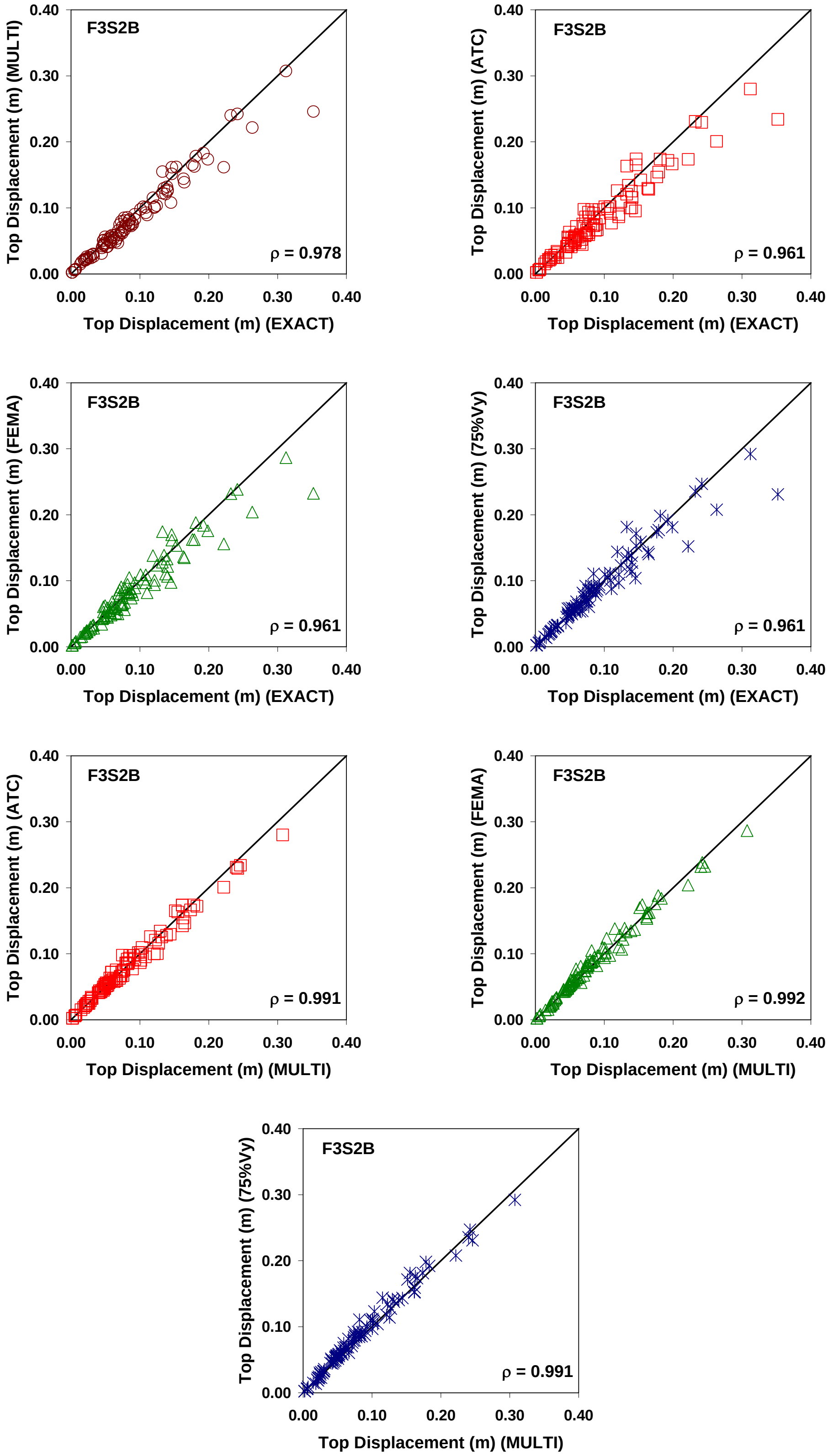


Figure A.5.3 Comparison of Approximate Results with respect to ‘EXACT’ and ‘MULTI’ Values of Maximum Top Displacement for Frame ‘F3S2B’

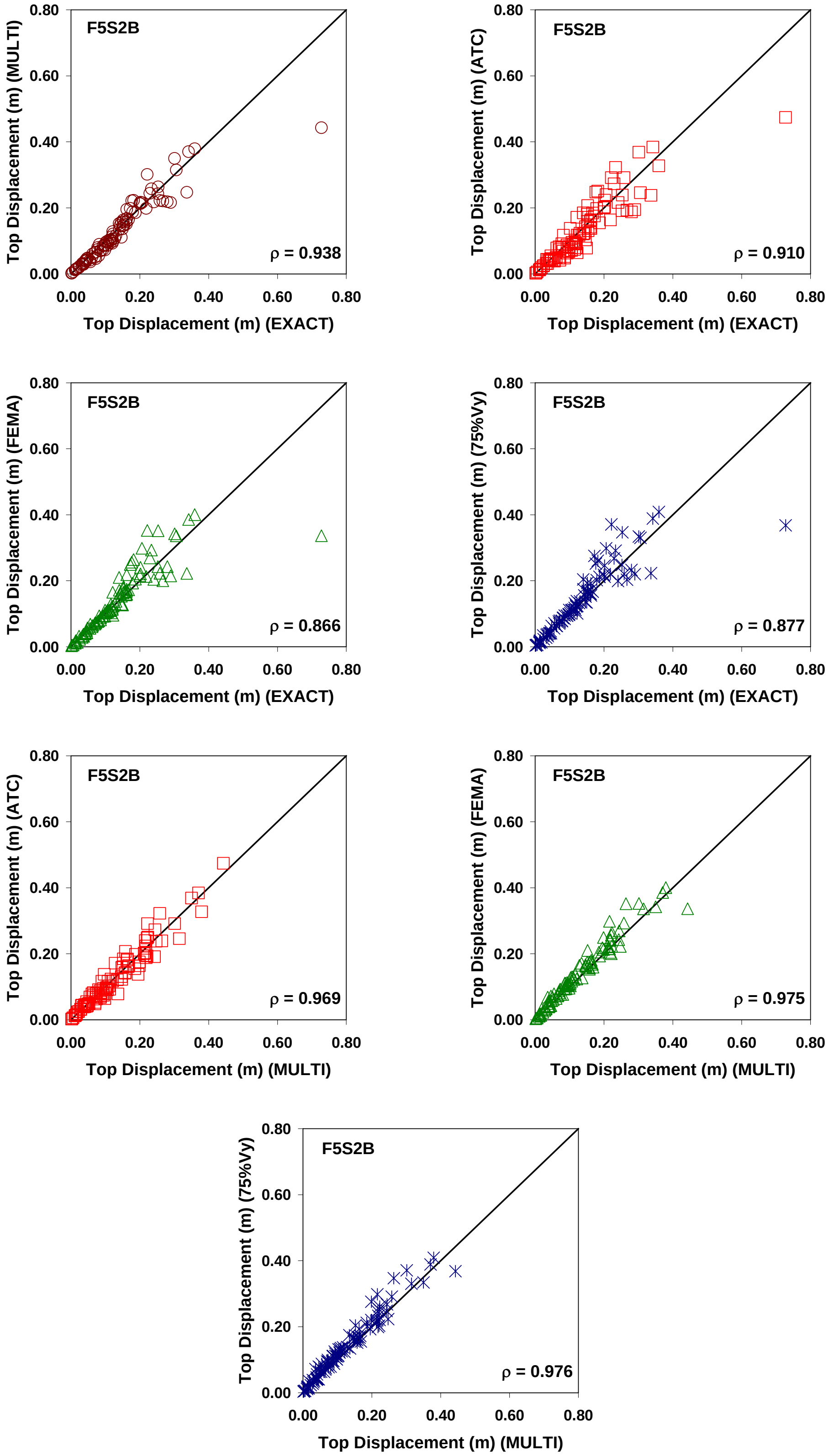


Figure A.5.4 Comparison of Approximate Results with respect to ‘EXACT’ and ‘MULTI’ Values of Maximum Top Displacement for Frame ‘F5S2B’

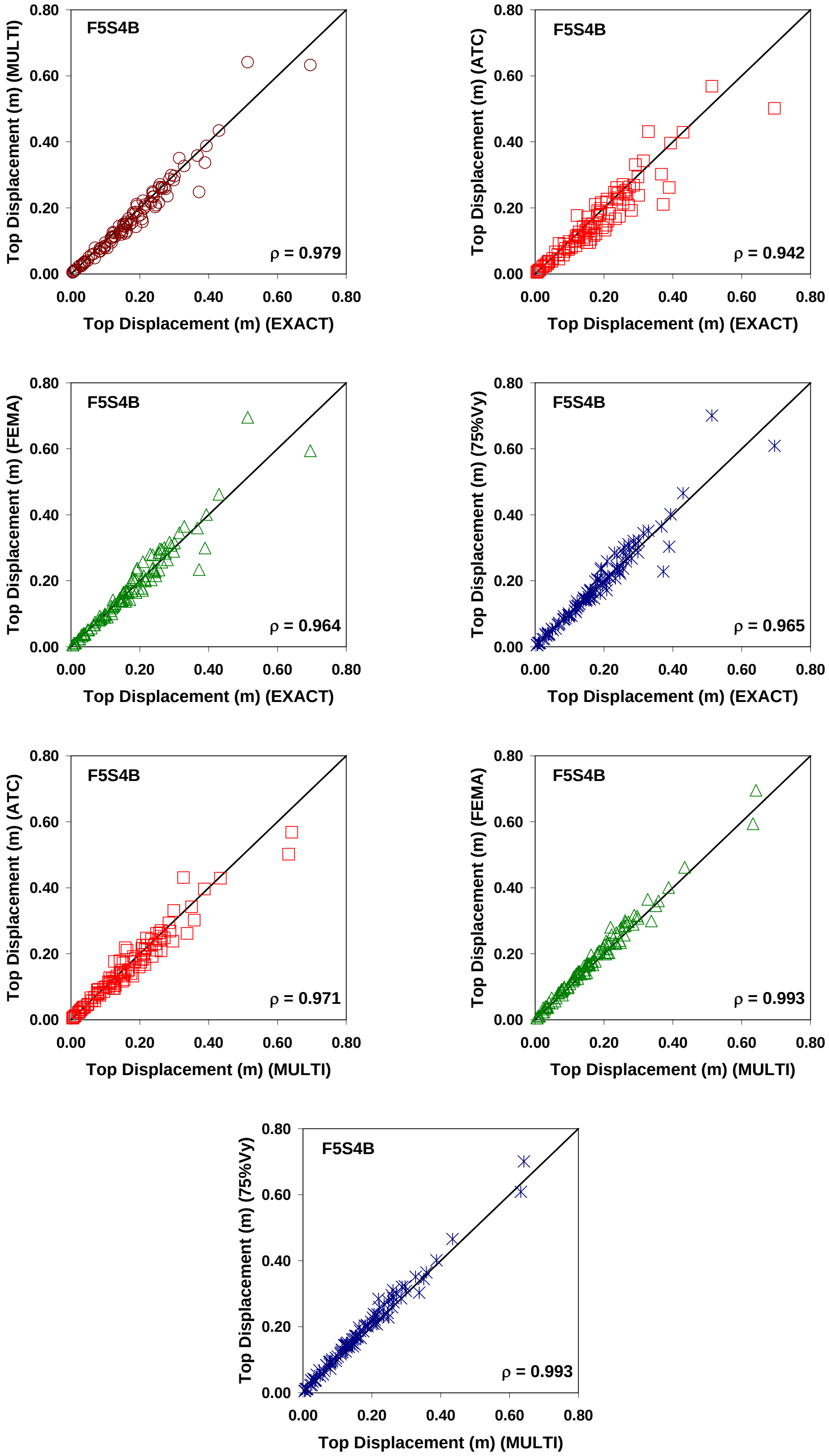


Figure A.5.5 Comparison of Approximate Results with respect to ‘EXACT’ and ‘MULTI’ Values of Maximum Top Displacement for Frame ‘F5S4B’

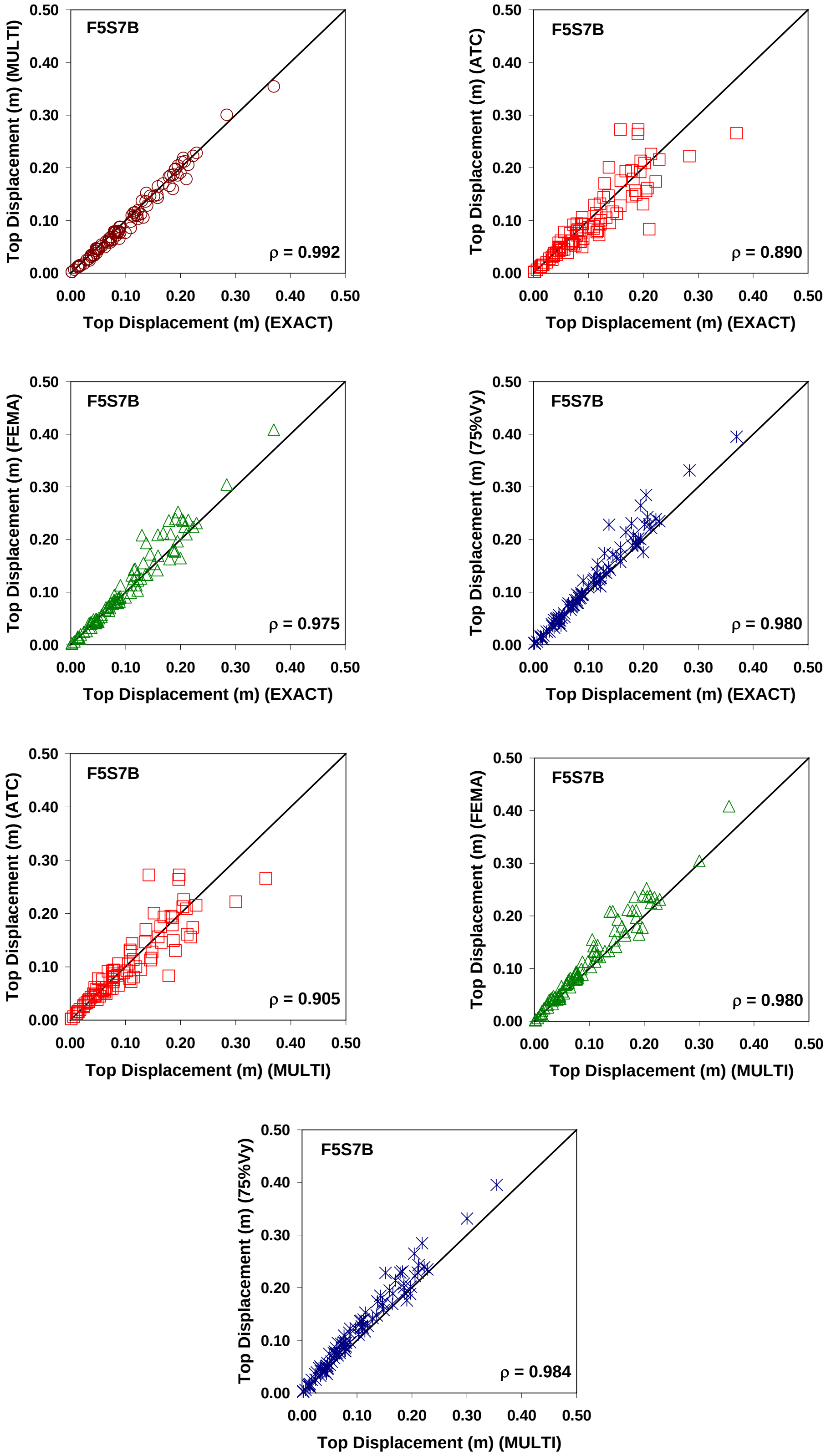


Figure A.5.6 Comparison of Approximate Results with respect to 'EXACT' and 'MULTI' Values of Maximum Top Displacement for Frame 'F5S7B'

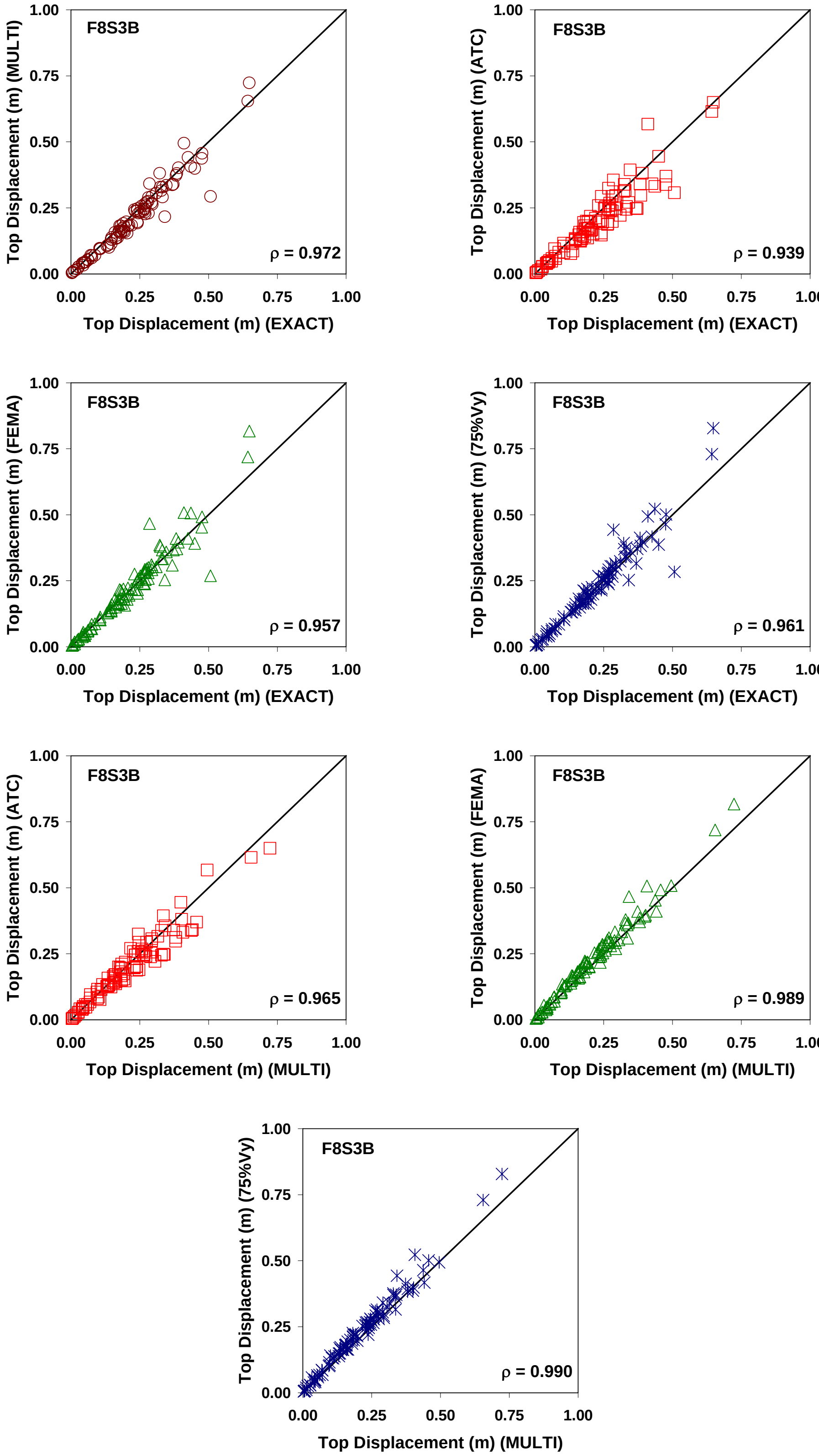


Figure A.5.7 Comparison of Approximate Results with respect to ‘EXACT’ and ‘MULTI’ Values of Maximum Top Displacement for Frame ‘F8S3B’

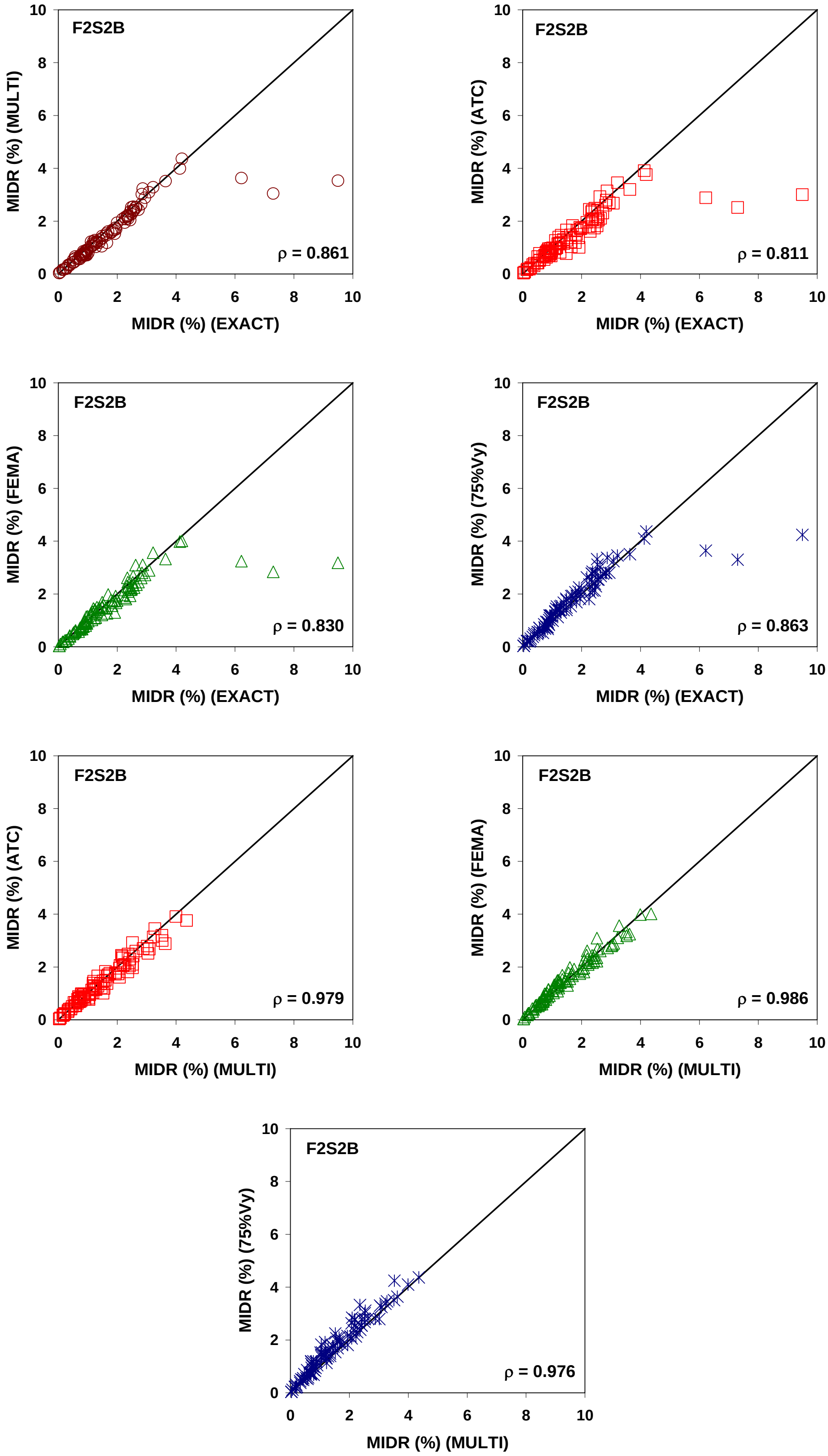


Figure A.5.8 Comparison of Approximate Results with respect to ‘EXACT’ and ‘MULTI’ Values of Maximum Inter-Story Drift Ratio for Frame ‘F2S2B’

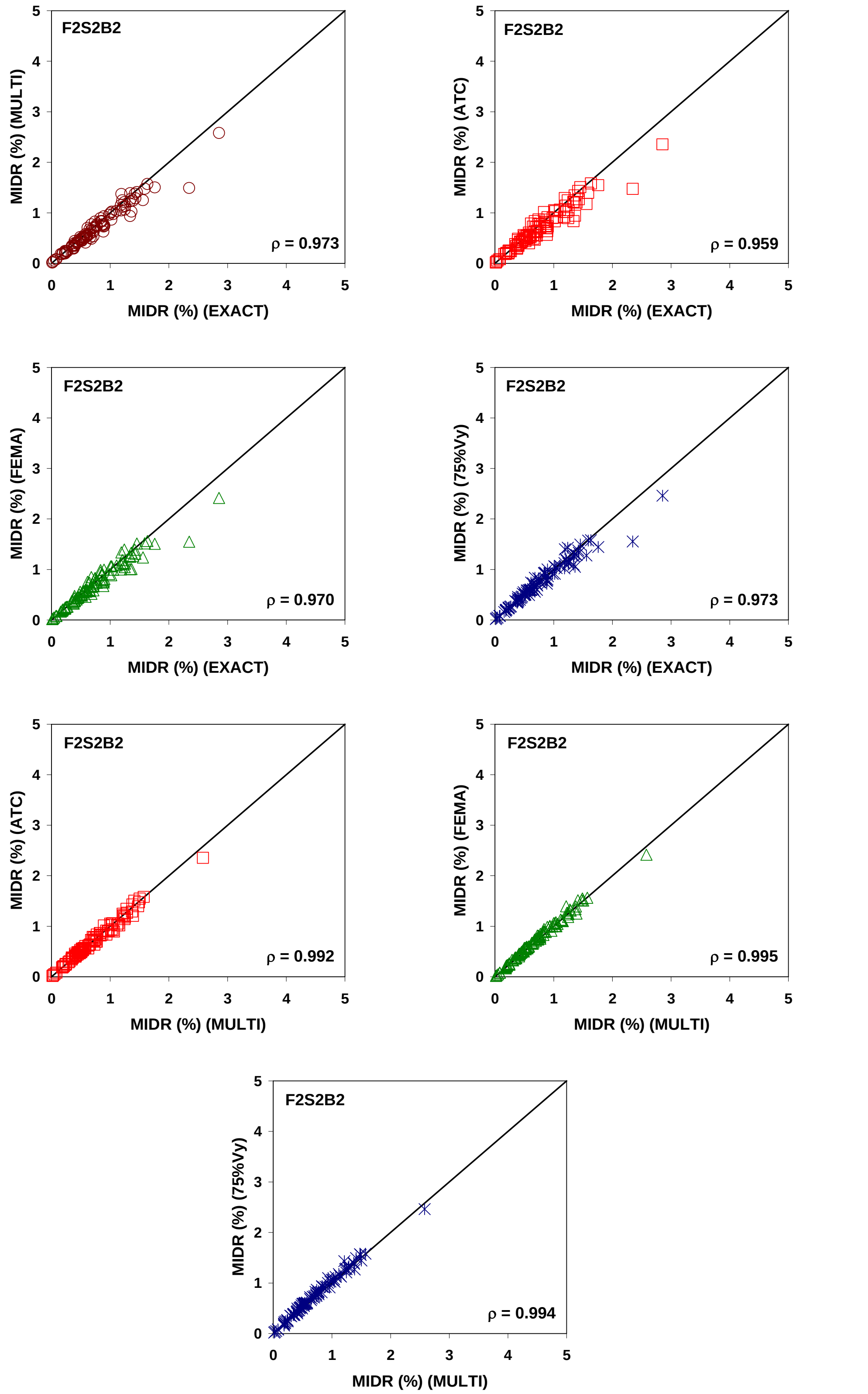


Figure A.5.9 Comparison of Approximate Results with respect to ‘EXACT’ and ‘MULTI’ Values of Maximum Inter-Story Drift Ratio for Frame ‘F2S2B2’

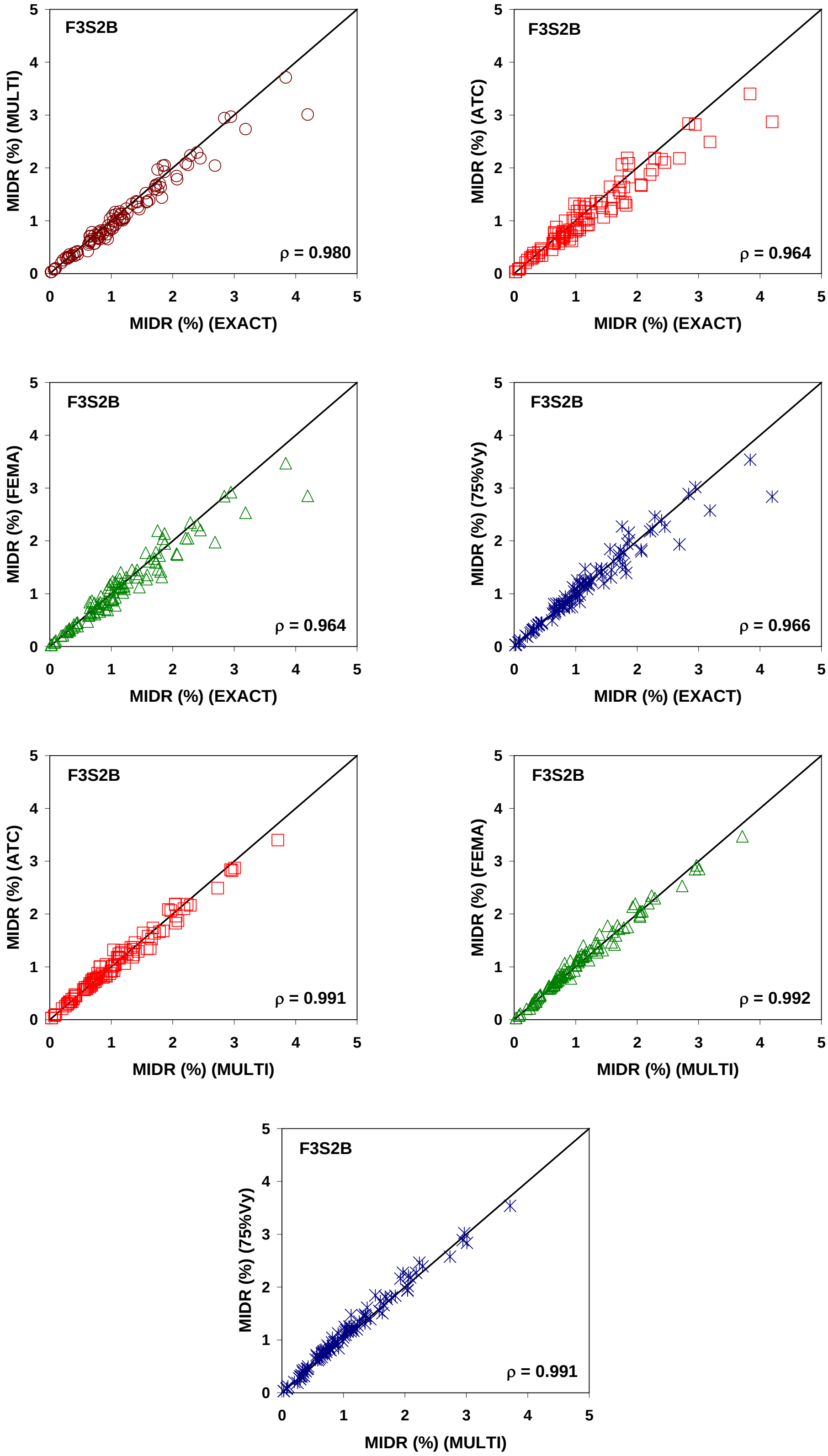


Figure A.5.10 Comparison of Approximate Results with respect to 'EXACT' and 'MULTI' Values of Maximum Inter-Story Drift Ratio for Frame 'F3S2B'

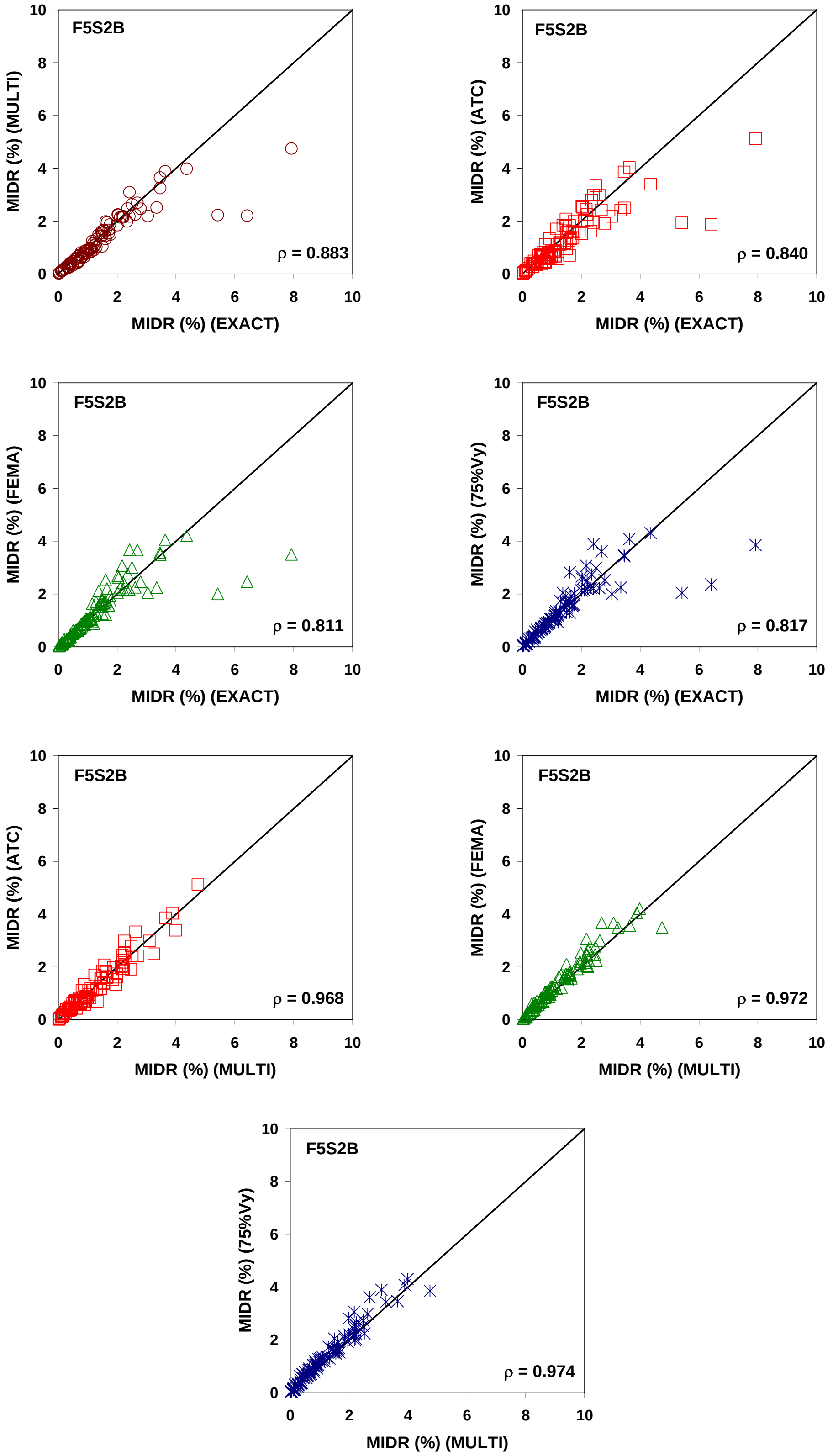


Figure A.5.11 Comparison of Approximate Results with respect to ‘EXACT’ and ‘MULTI’ Values of Maximum Inter-Story Drift Ratio for Frame ‘F5S2B’

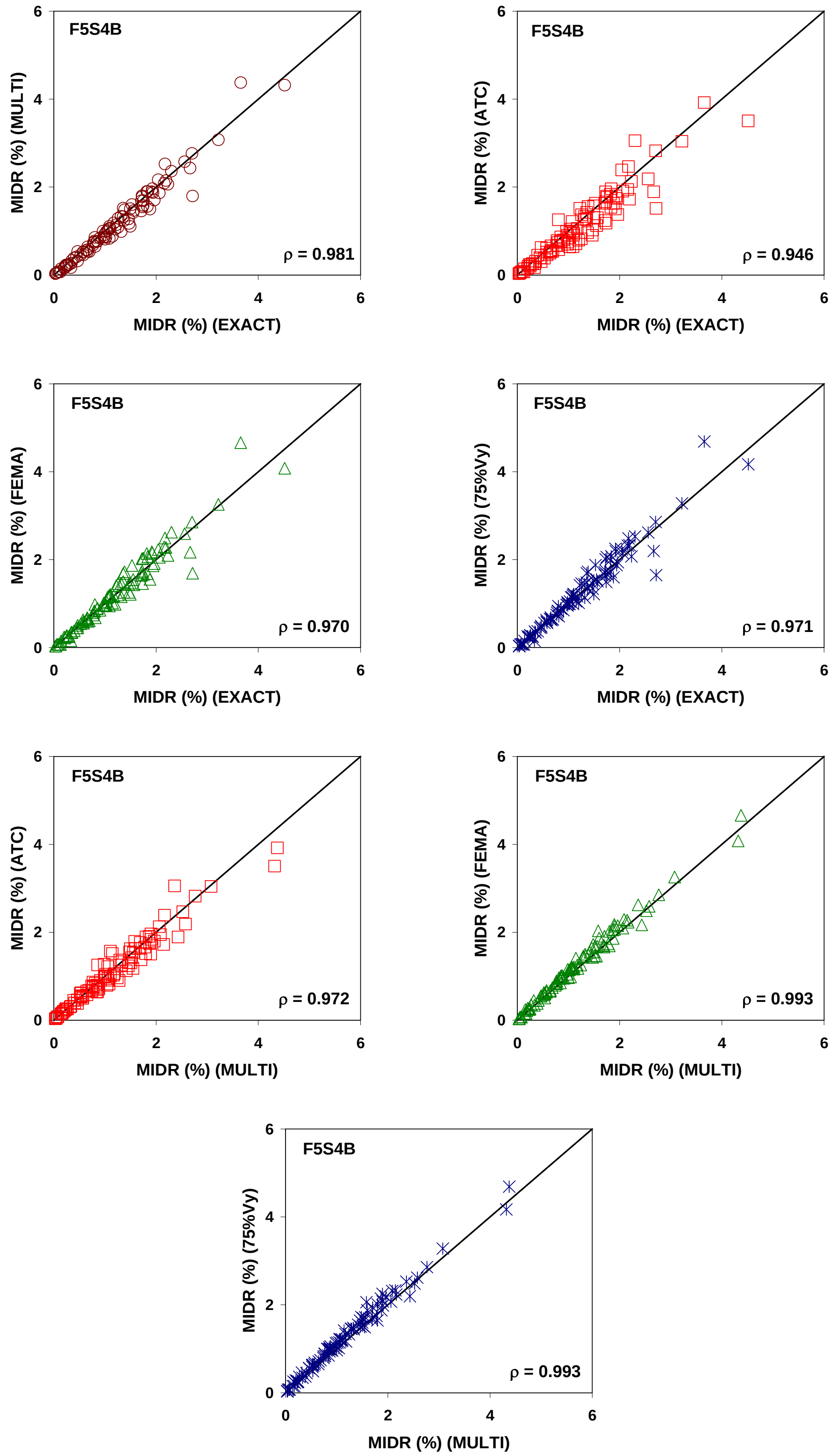


Figure A.5.12 Comparison of Approximate Results with respect to 'EXACT' and 'MULTI' Values of Maximum Inter-Story Drift Ratio for Frame 'F5S4B'

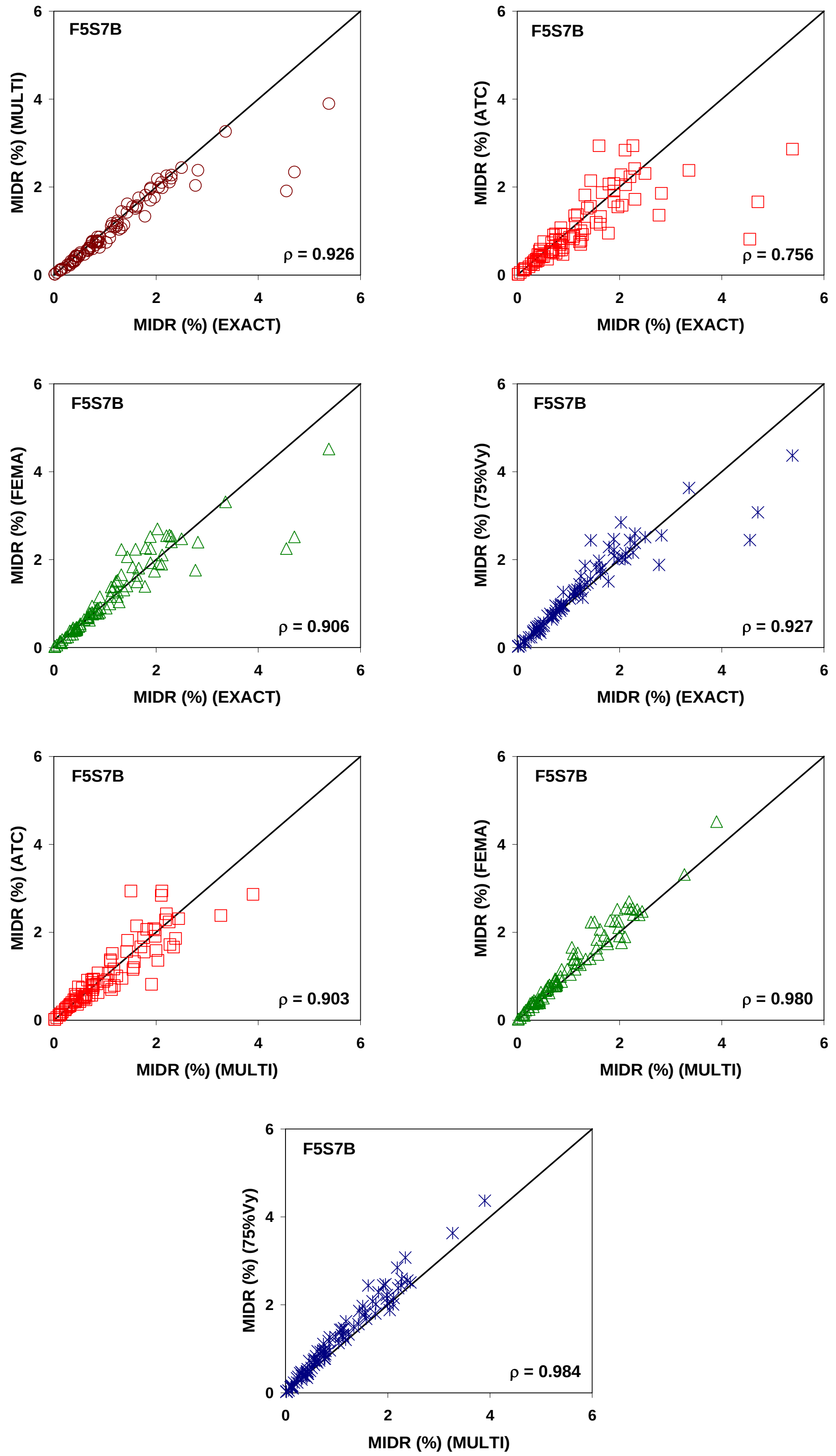


Figure A.5.13 Comparison of Approximate Results with respect to ‘EXACT’ and ‘MULTI’ Values of Maximum Inter-Story Drift Ratio for Frame ‘F5S7B’

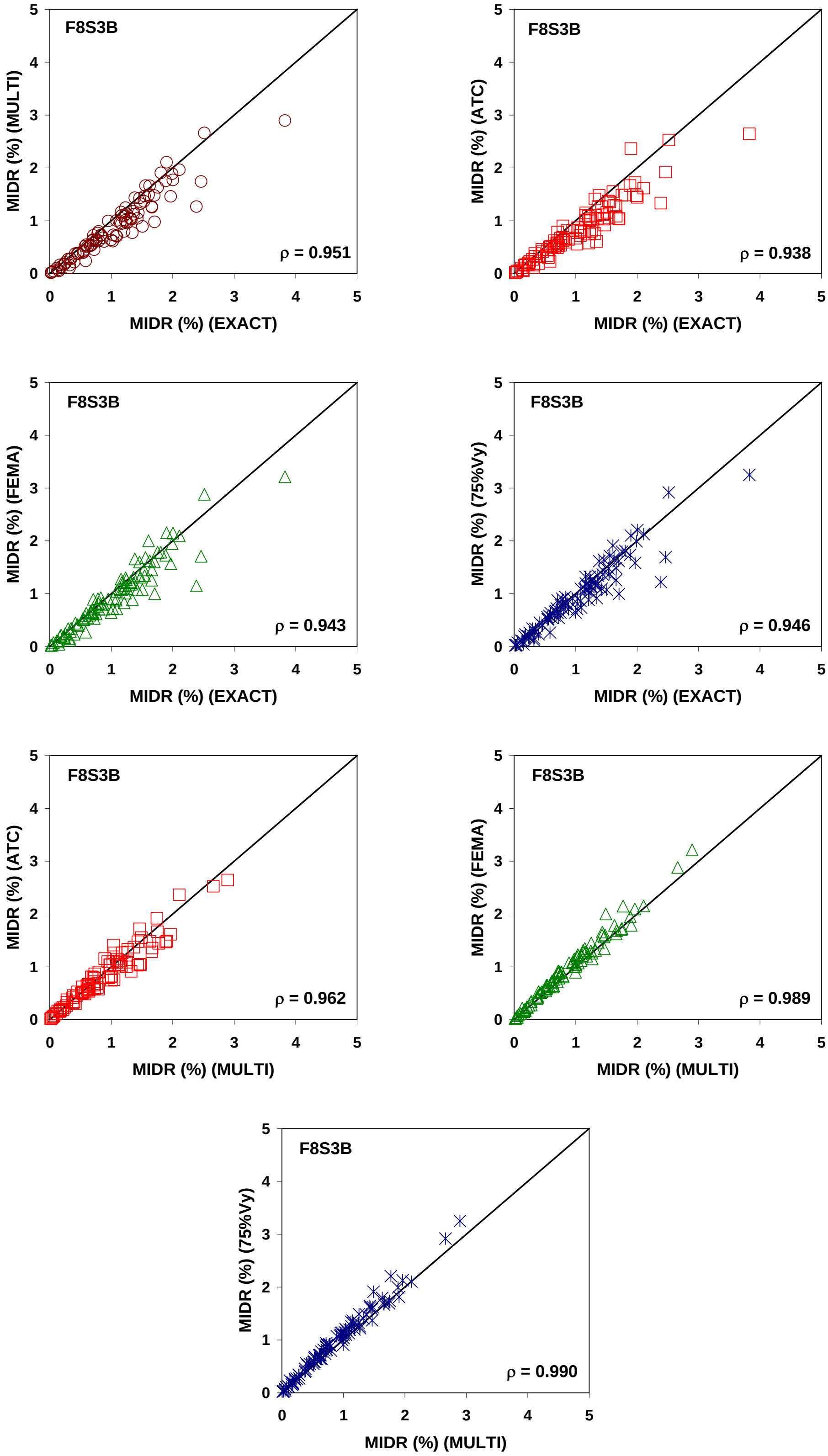


Figure A.5.14 Comparison of Approximate Results with respect to ‘EXACT’ and ‘MULTI’ Values of Maximum Inter-Story Drift Ratio for Frame ‘F8S3B’

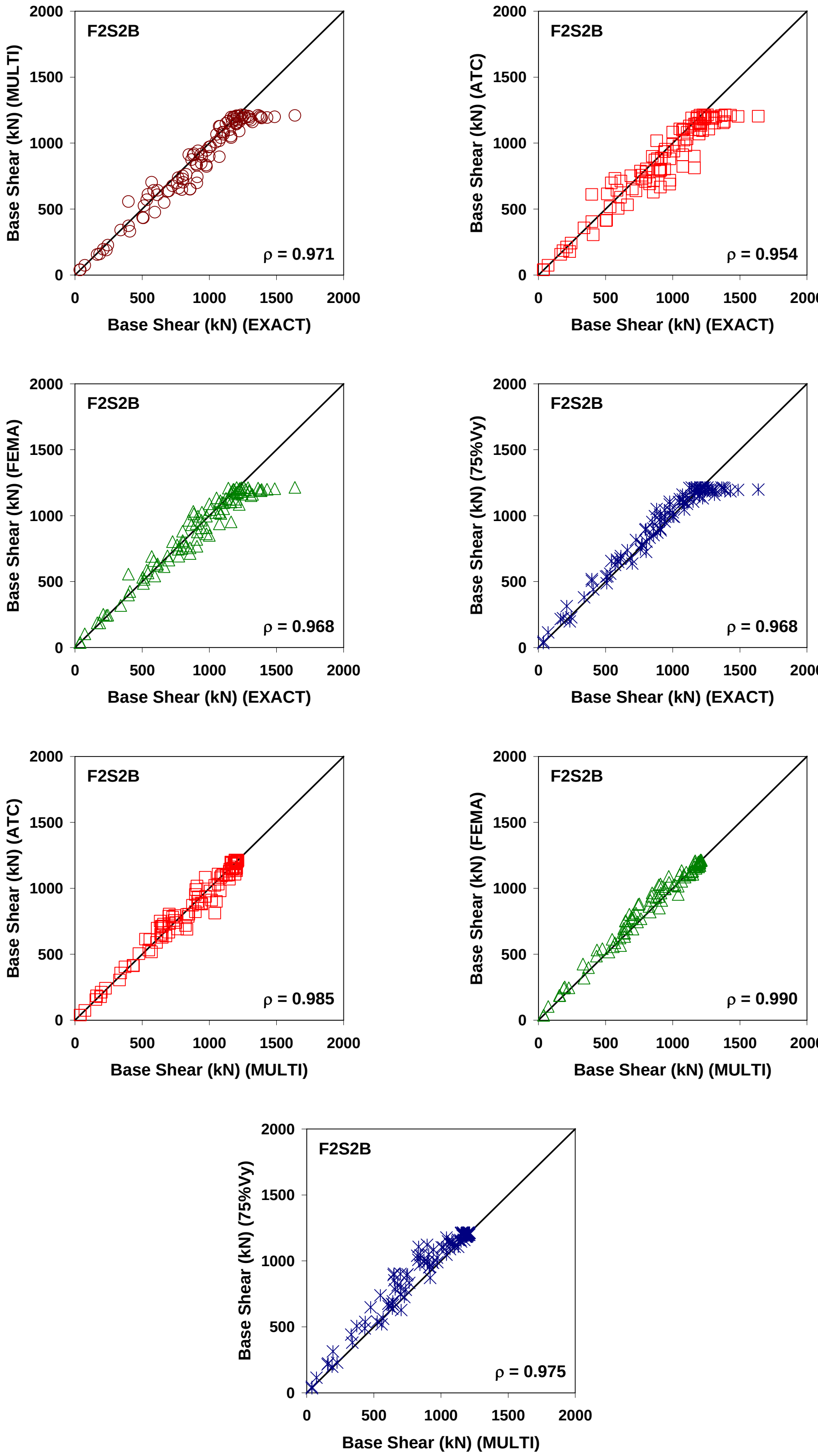


Figure A.5.15 Comparison of Approximate Results with respect to ‘EXACT’ and ‘MULTI’ Values of Maximum Base Shear for Frame ‘F2S2B’

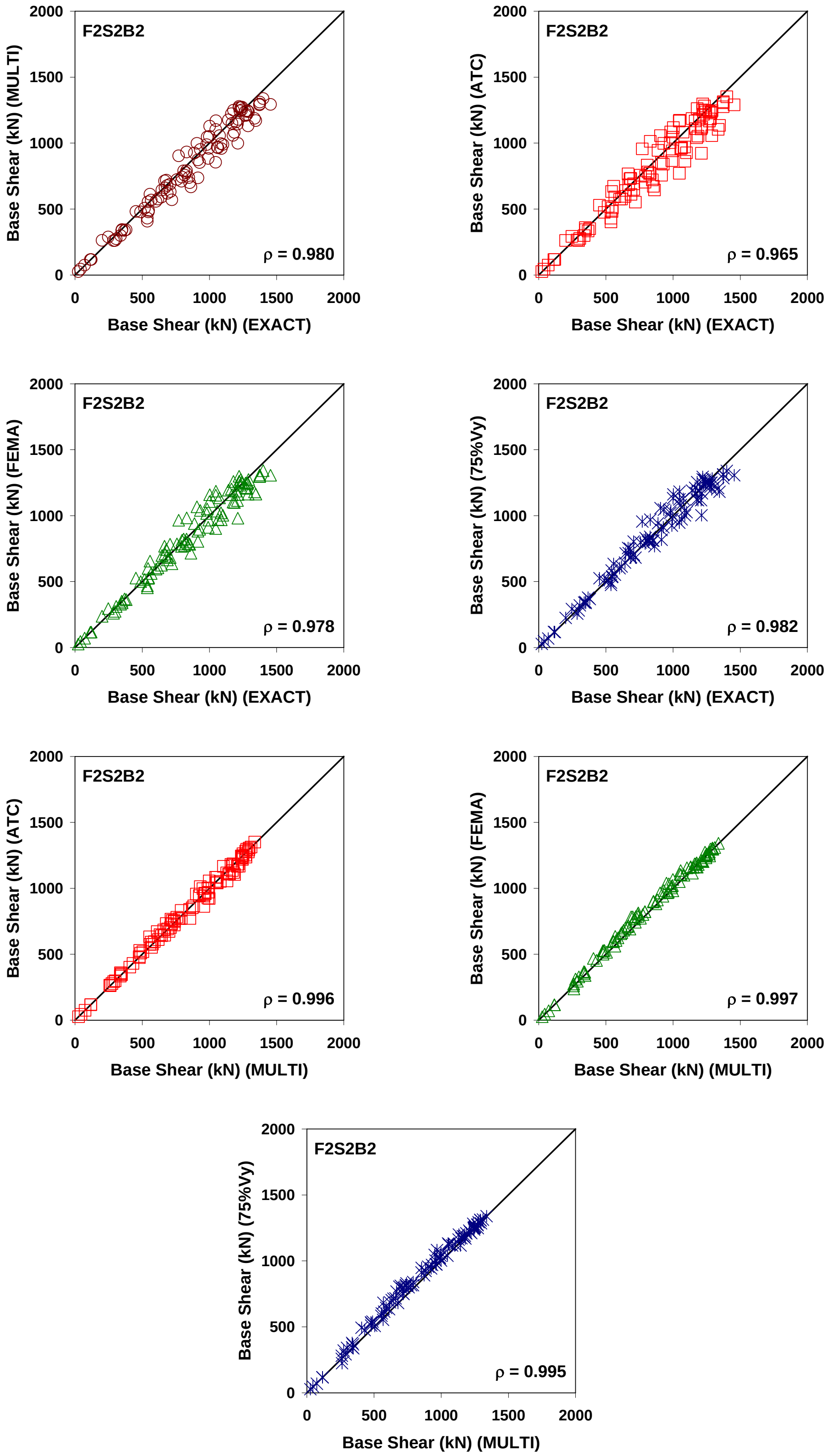


Figure A.5.16 Comparison of Approximate Results with respect to 'EXACT' and 'MULTI' Values of Maximum Base Shear for Frame 'F2S2B2'

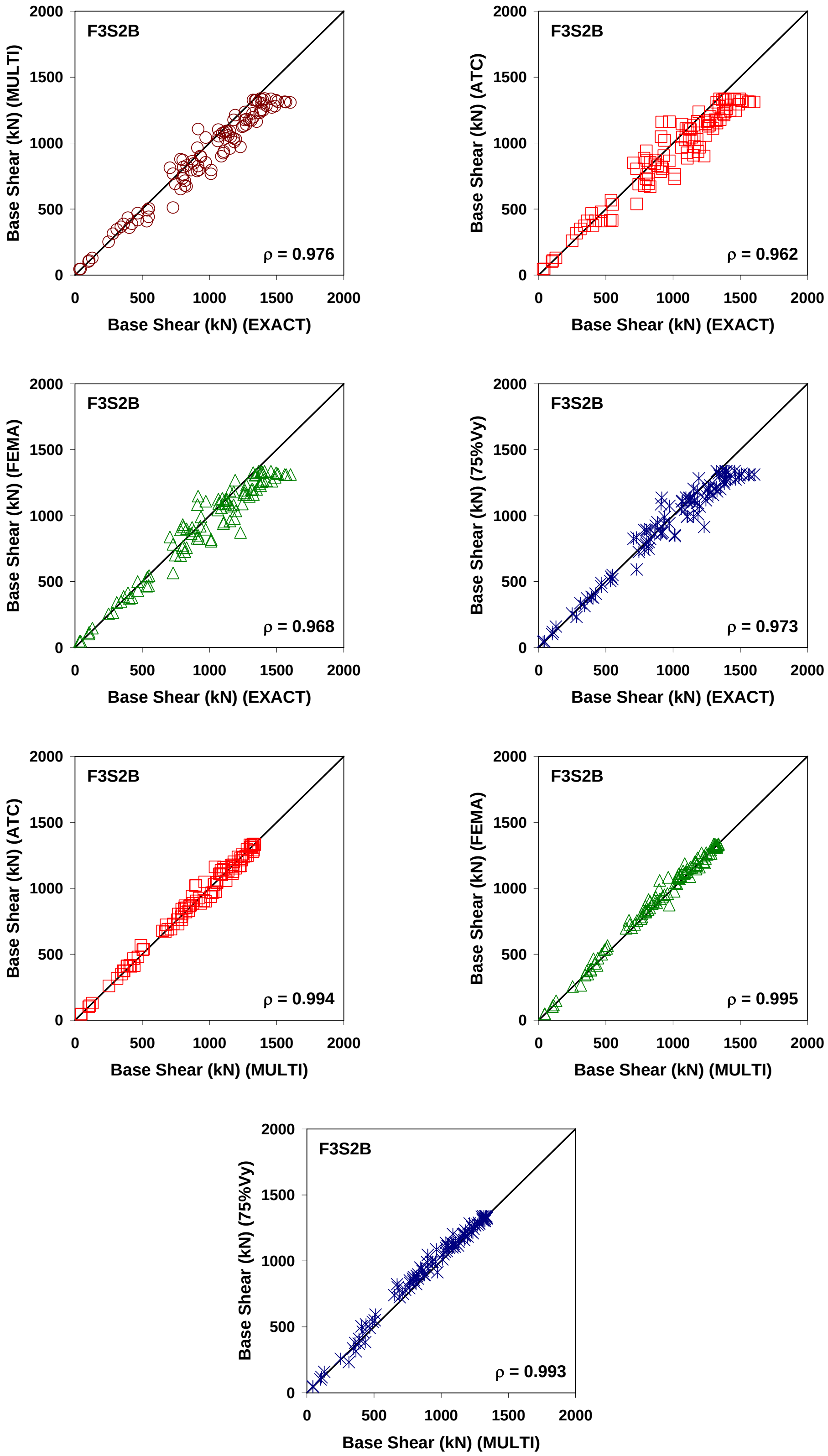


Figure A.5.17 Comparison of Approximate Results with respect to ‘EXACT’ and ‘MULTI’ Values of Maximum Base Shear for Frame ‘F3S2B’

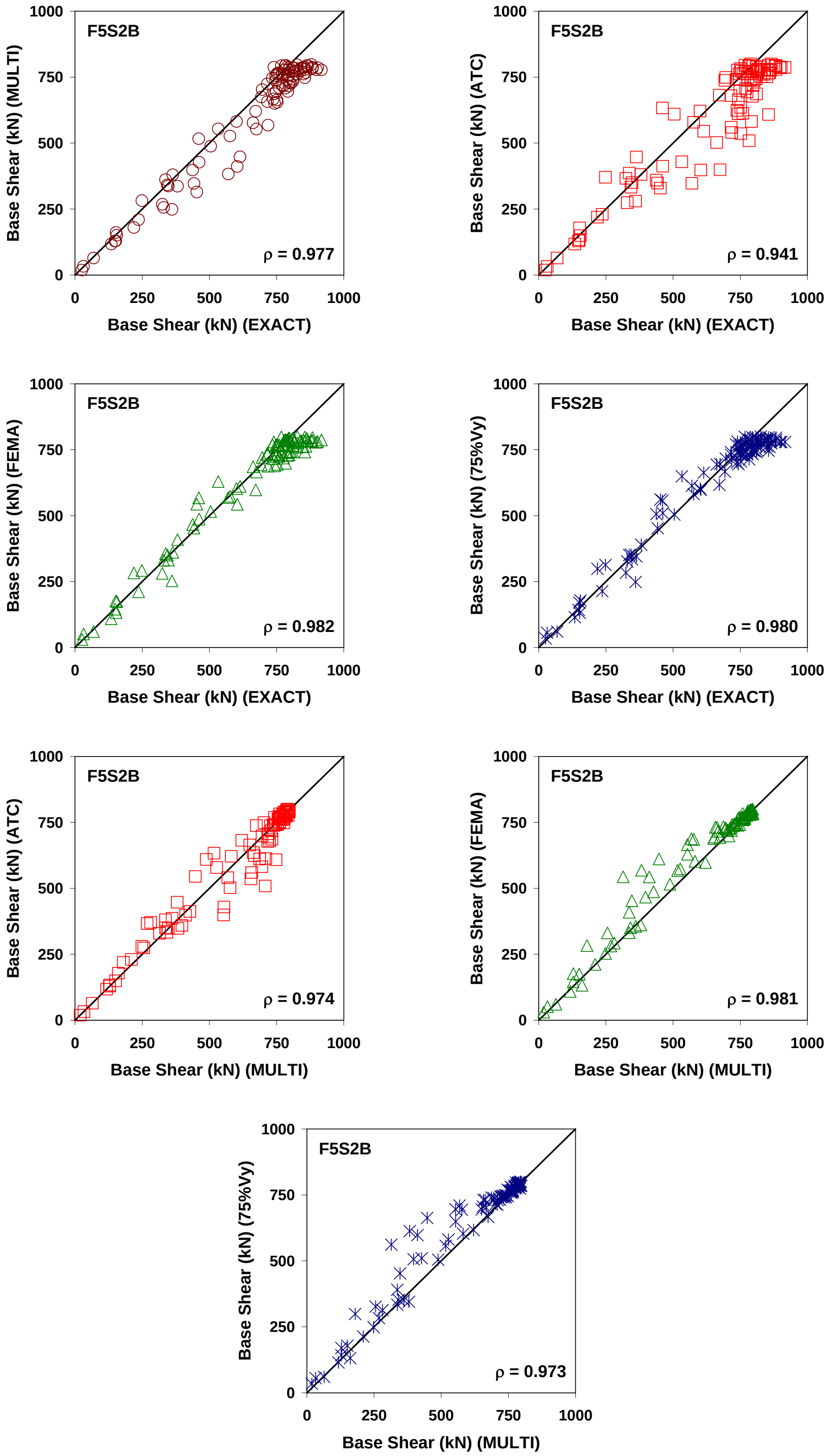


Figure A.5.18 Comparison of Approximate Results with respect to ‘EXACT’ and ‘MULTI’ Values of Maximum Base Shear for Frame ‘F5S2B’

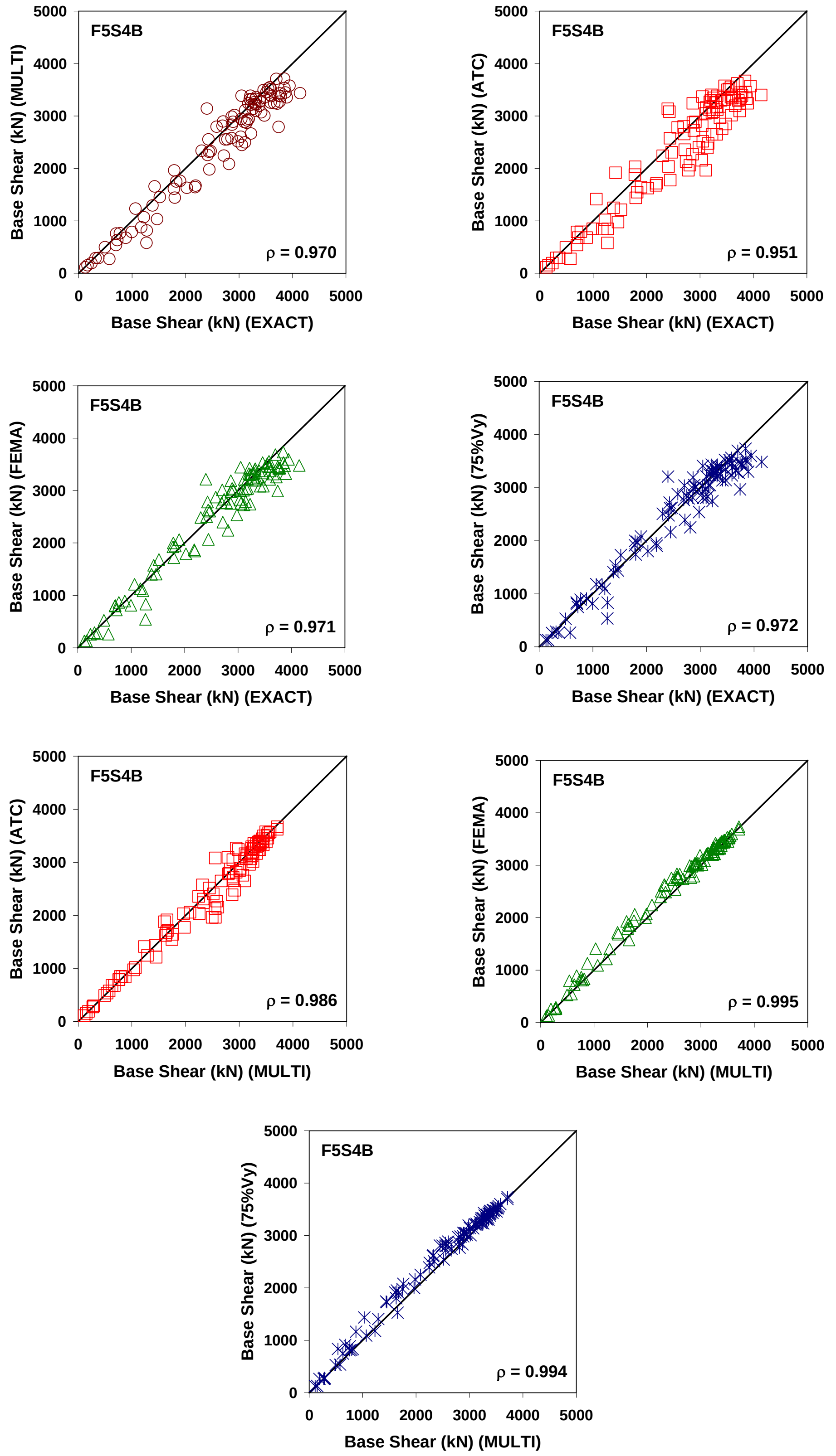


Figure A.5.19 Comparison of Approximate Results with respect to ‘EXACT’ and ‘MULTI’ Values of Maximum Base Shear for Frame ‘F5S4B’

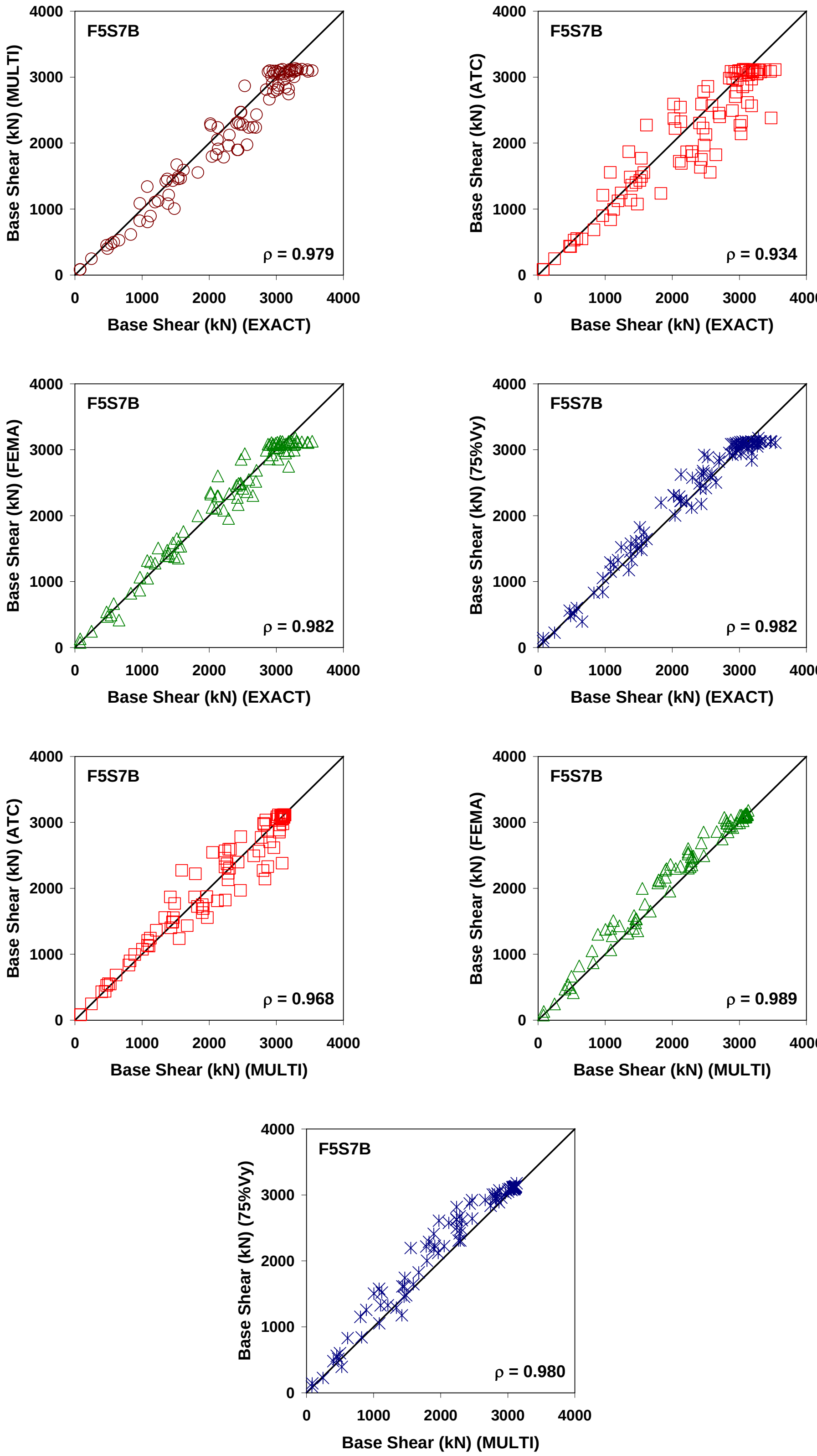


Figure A.5.20 Comparison of Approximate Results with respect to 'EXACT' and 'MULTI' Values of Maximum Base Shear for Frame 'F5S7B'

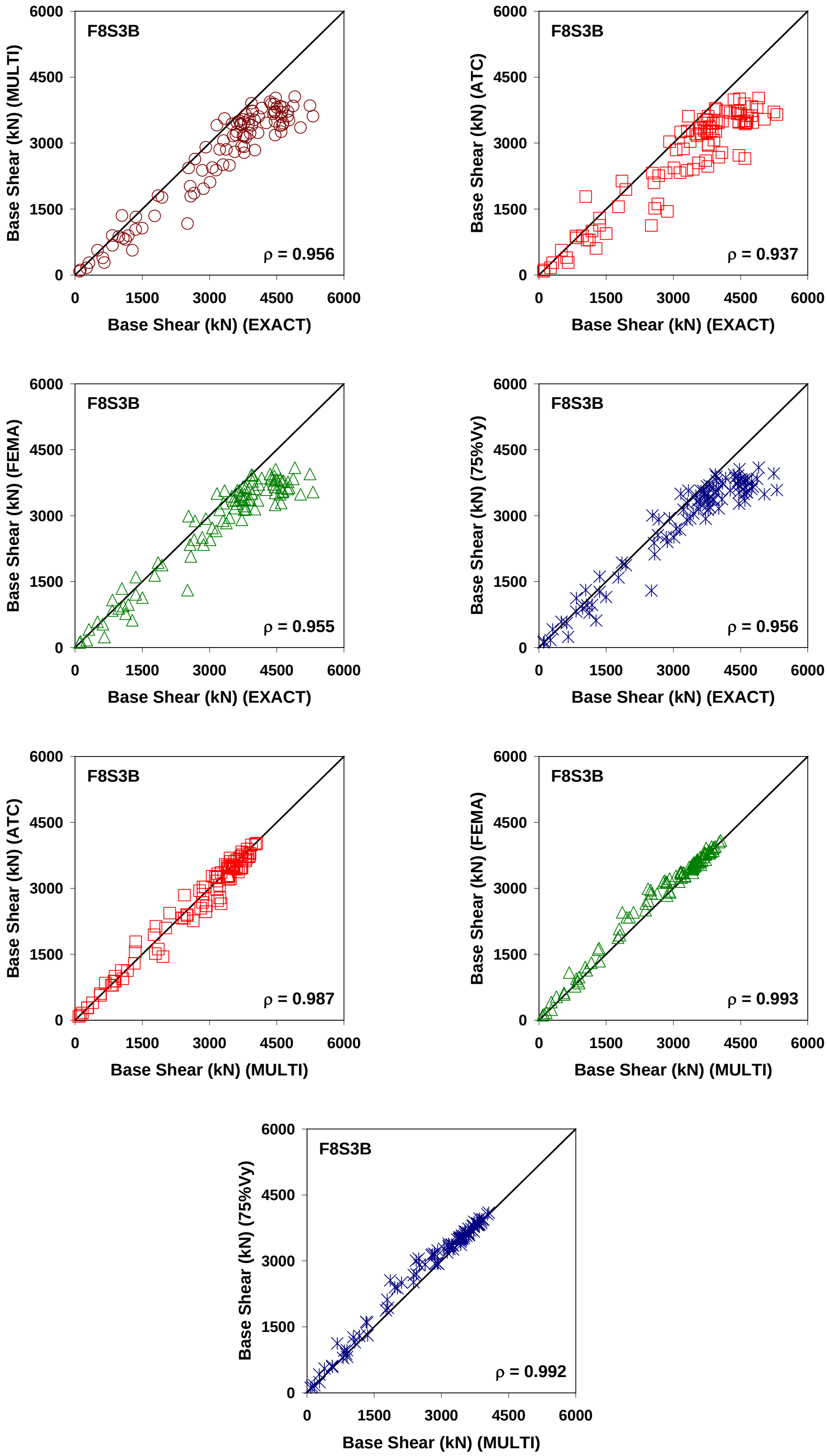


Figure A.5.21 Comparison of Approximate Results with respect to 'EXACT' and 'MULTI' Values of Maximum Base Shear for Frame 'F8S3B'

A.6 DRIFT-WISE COMPARISON GRAPHS

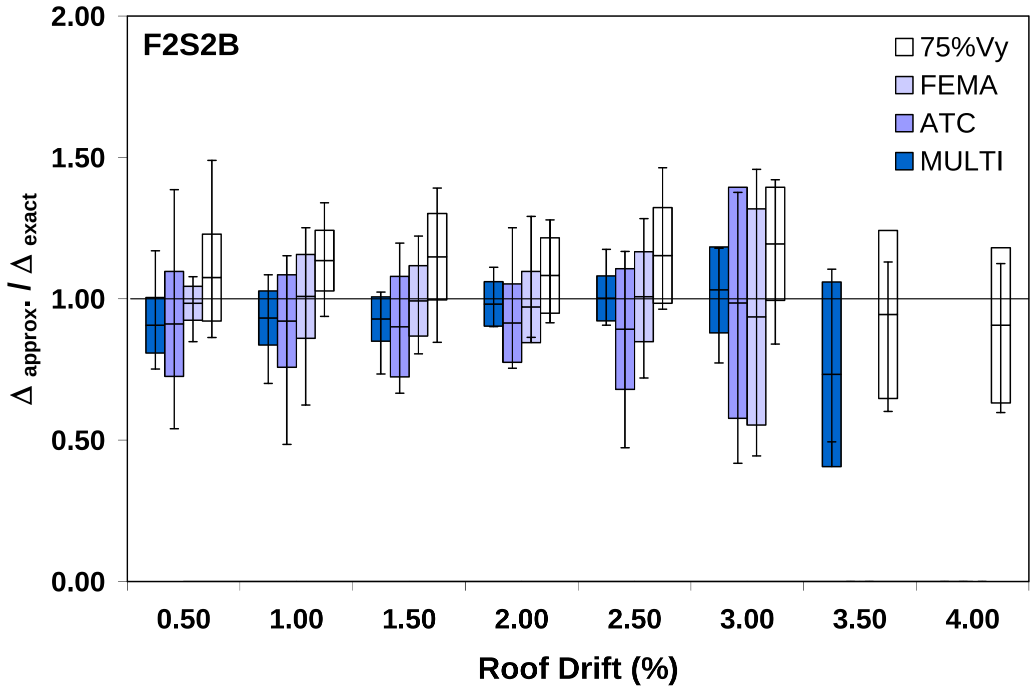


Figure A.6.1 Comparison of Approximations with respect to 'EXACT' Values of Maximum Top Displacement at Specified Global Roof Drifts for Frame 'F2S2B'

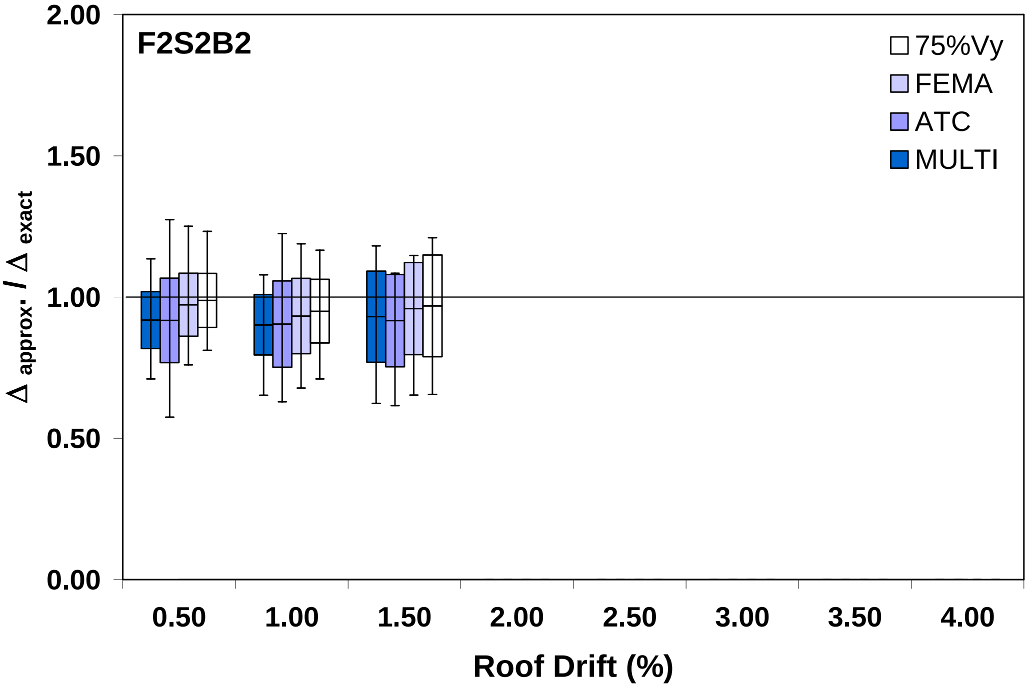


Figure A.6.2 Comparison of Approximations with respect to 'EXACT' Values of Maximum Top Displacement at Specified Global Roof Drifts for Frame 'F2S2B2'

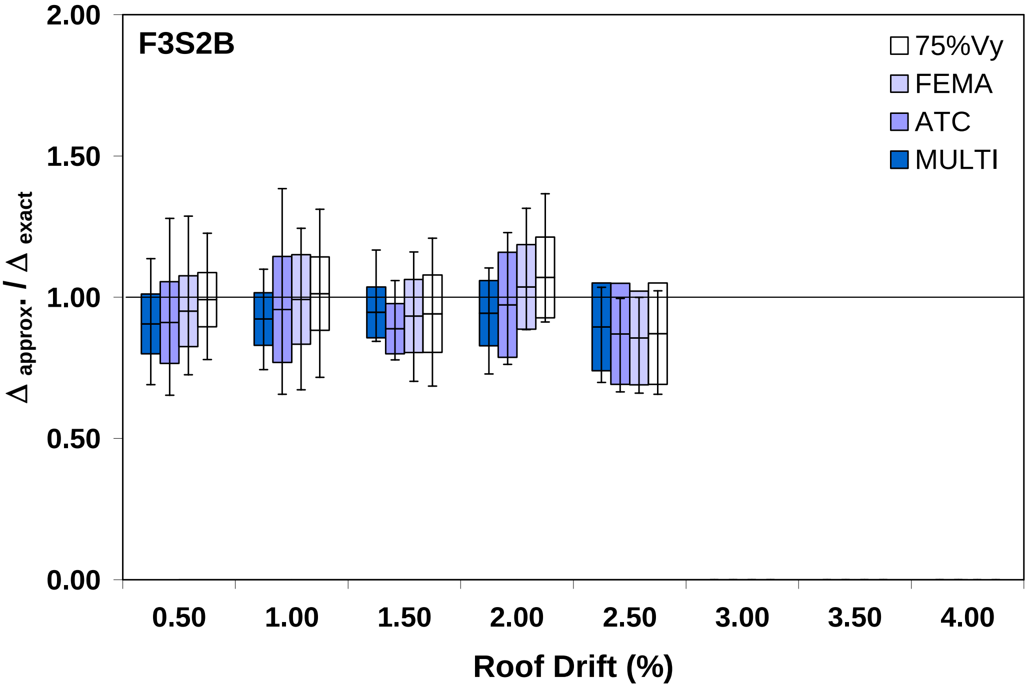


Figure A.6.3 Comparison of Approximations with respect to 'EXACT' Values of Maximum Top Displacement at Specified Global Roof Drifts for Frame 'F3S2B'

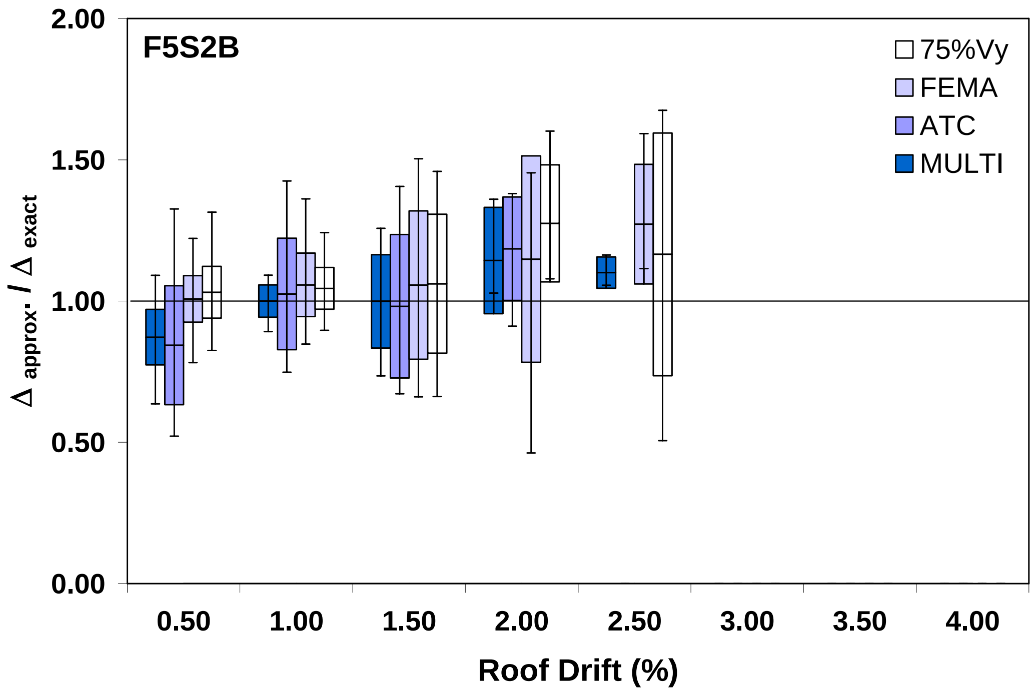


Figure A.6.4 Comparison of Approximations with respect to 'EXACT' Values of Maximum Top Displacement at Specified Global Roof Drifts for Frame 'F5S2B'

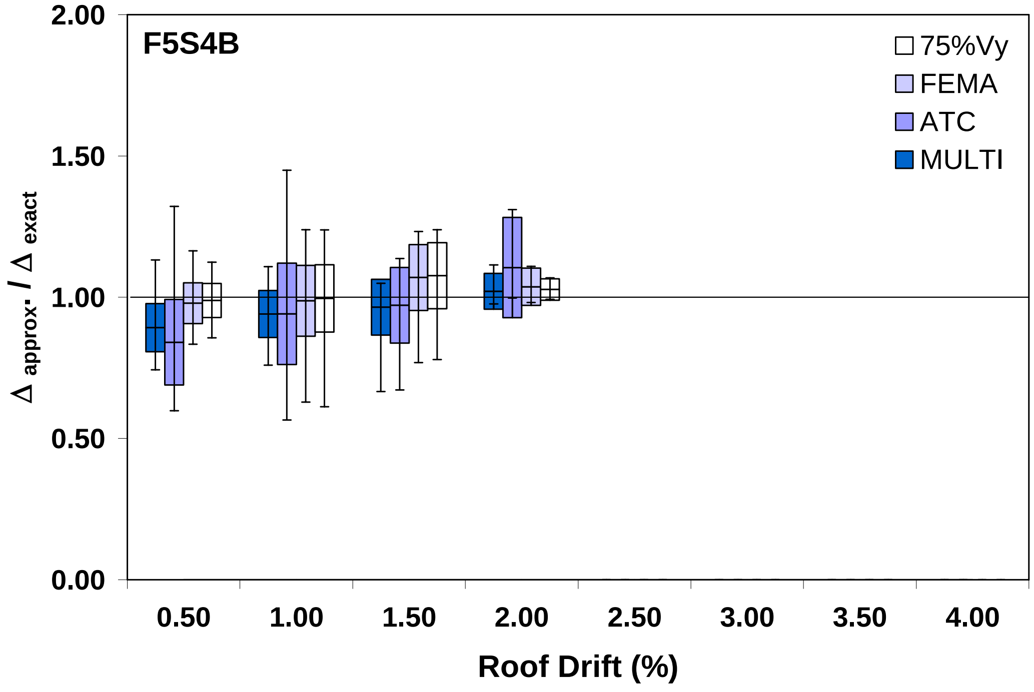


Figure A.6.5 Comparison of Approximations with respect to 'EXACT' Values of Maximum Top Displacement at Specified Global Roof Drifts for Frame 'F5S4B'

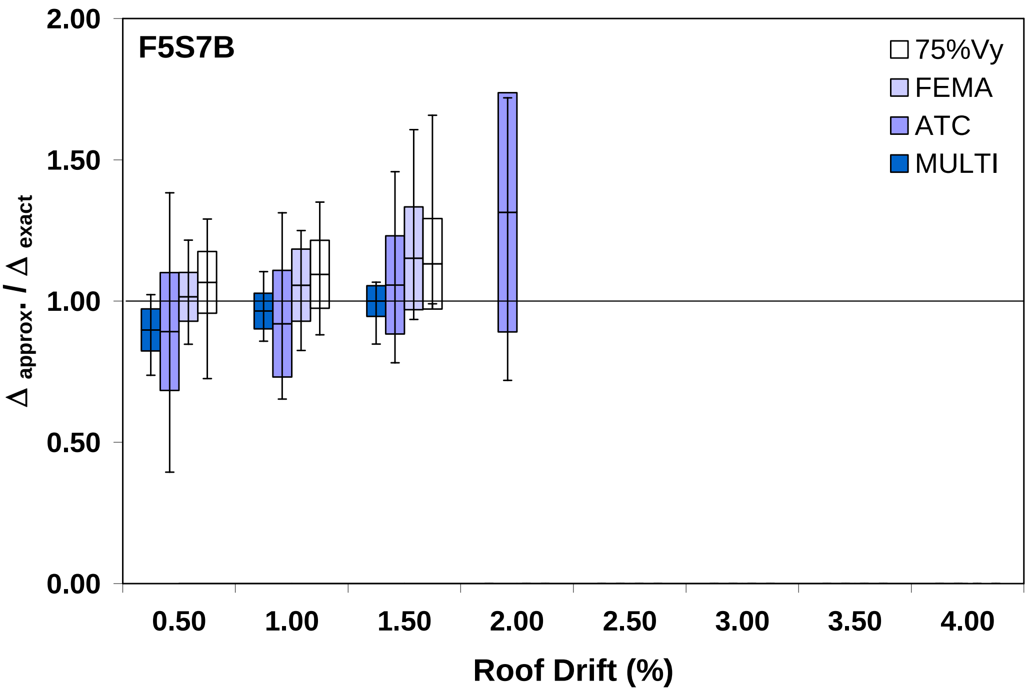


Figure A.6.6 Comparison of Approximations with respect to 'EXACT' Values of Maximum Top Displacement at Specified Global Roof Drifts for Frame 'F5S7B'

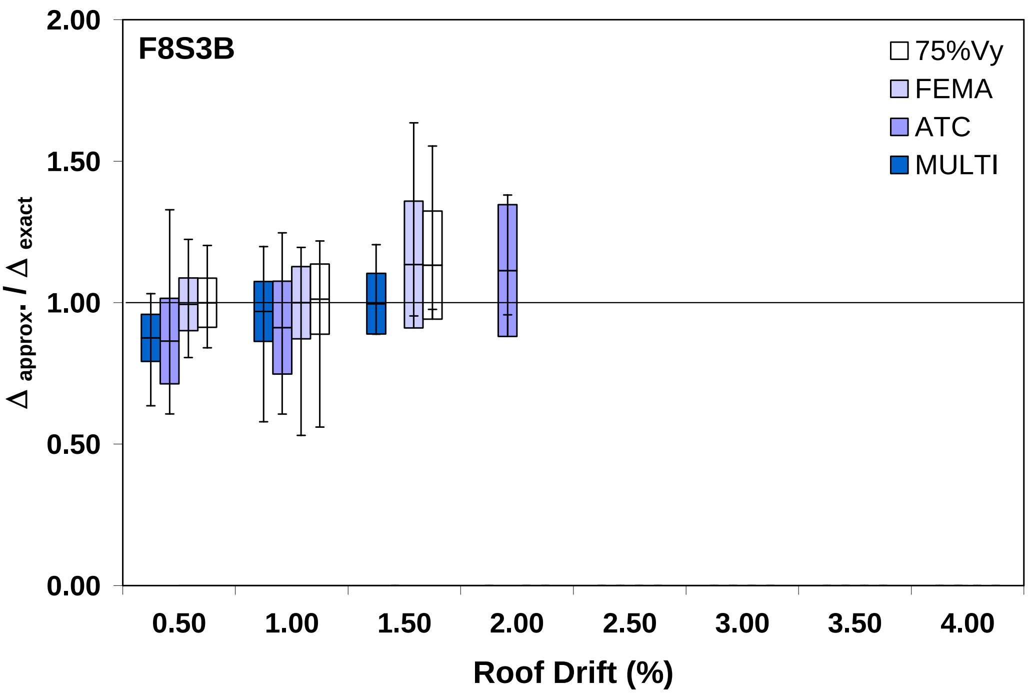


Figure A.6.7 Comparison of Approximations with respect to 'EXACT' Values of Maximum Top Displacement at Specified Global Roof Drifts for Frame 'F8S3B'

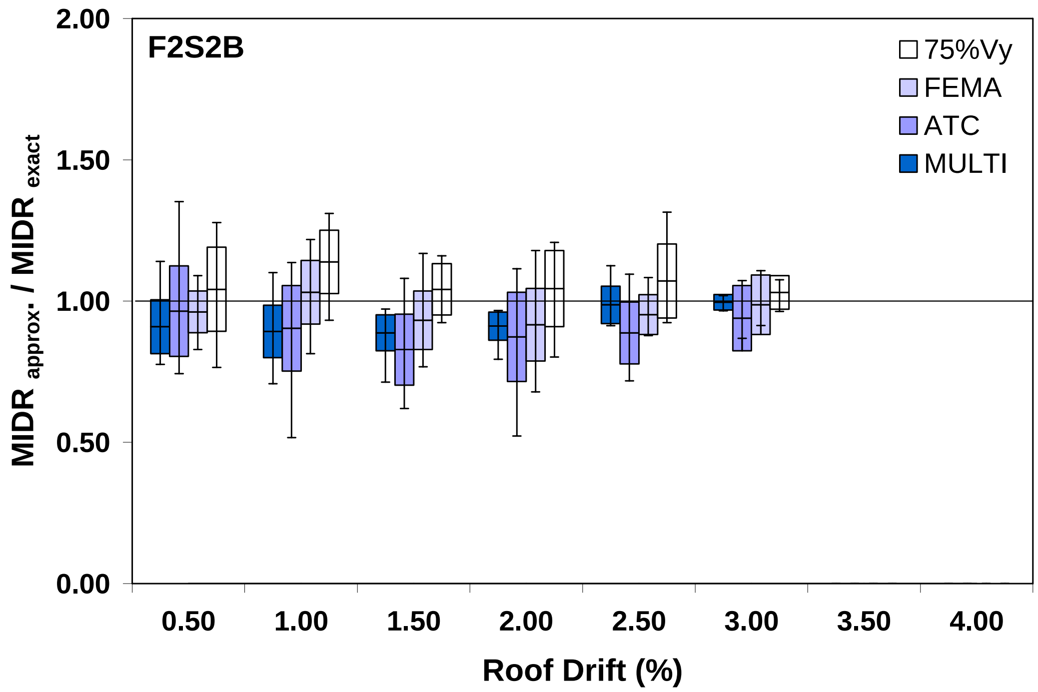


Figure A.6.8 Comparison of Approximations with respect to 'EXACT' Values of Maximum Inter-Story Drift Ratio at Specified Global Roof Drifts for Frame 'F2S2B'

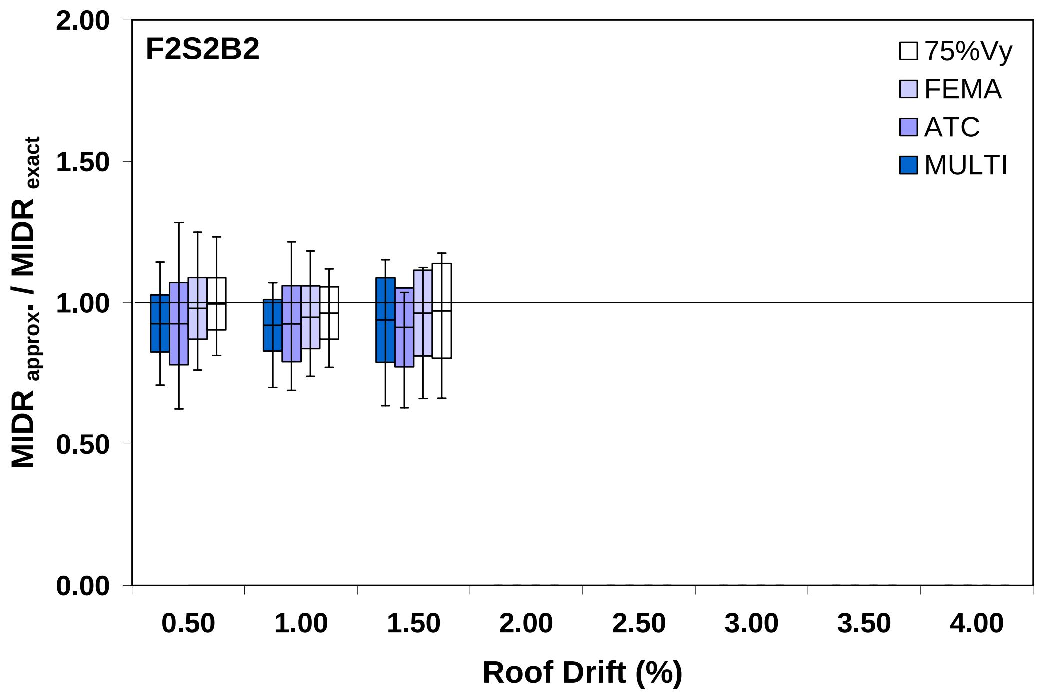


Figure A.6.9 Comparison of Approximations with respect to 'EXACT' Values of Maximum Inter-Story Drift Ratio at Specified Global Roof Drifts for Frame 'F2S2B2'

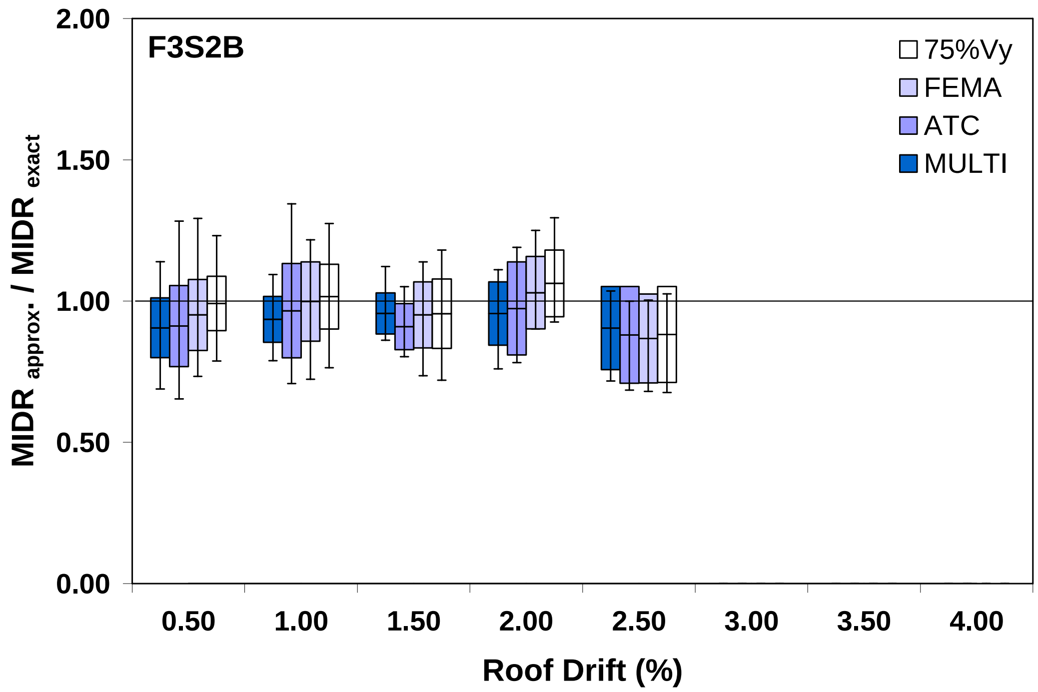


Figure A.6.10 Comparison of Approximations with respect to 'EXACT' Values of Maximum Inter-Story Drift Ratio at Specified Global Roof Drifts for Frame 'F3S2B'

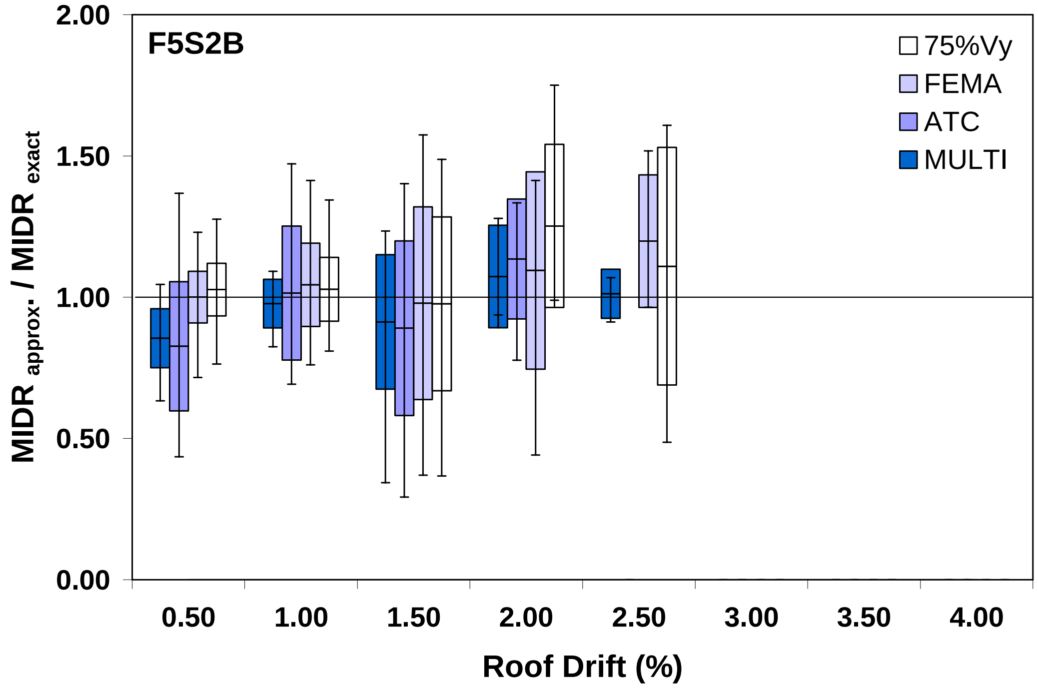


Figure A.6.11 Comparison of Approximations with respect to 'EXACT' Values of Maximum Inter-Story Drift Ratio at Specified Global Roof Drifts for Frame 'F5S2B'

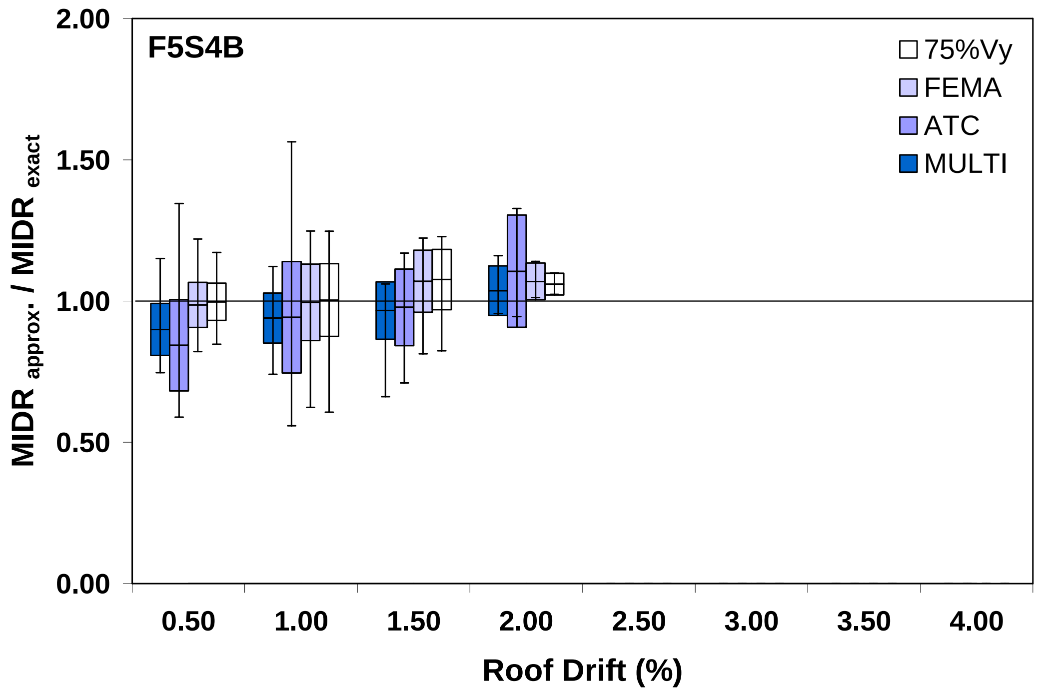


Figure A.6.12 Comparison of Approximations with respect to ‘EXACT’ Values of Maximum Inter-Story Drift Ratio at Specified Global Roof Drifts for Frame ‘F5S4B’

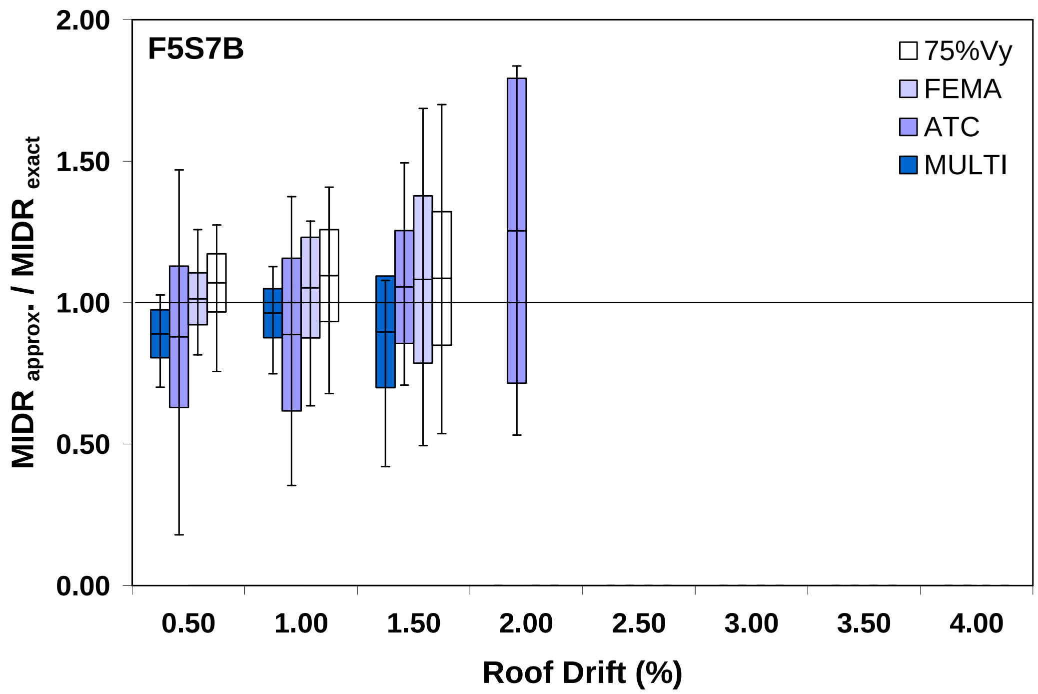


Figure A.6.13 Comparison of Approximations with respect to ‘EXACT’ Values of Maximum Inter-Story Drift Ratio at Specified Global Roof Drifts for Frame ‘F5S7B’

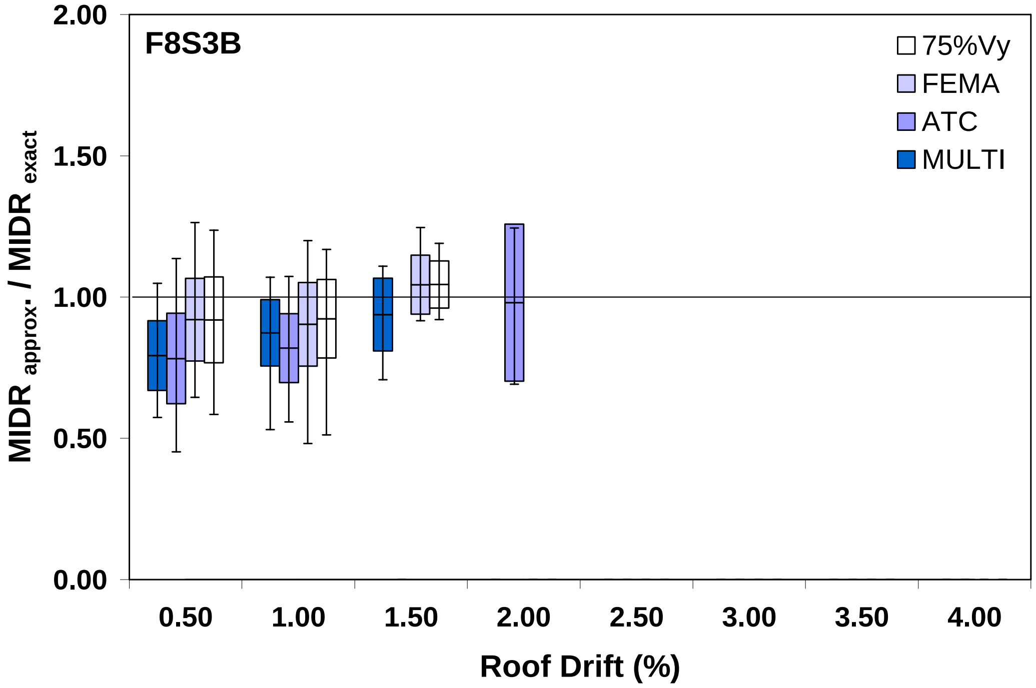


Figure A.6.14 Comparison of Approximations with respect to ‘EXACT’ Values of Maximum Inter-Story Drift Ratio at Specified Global Roof Drifts for Frame ‘F8S3B’

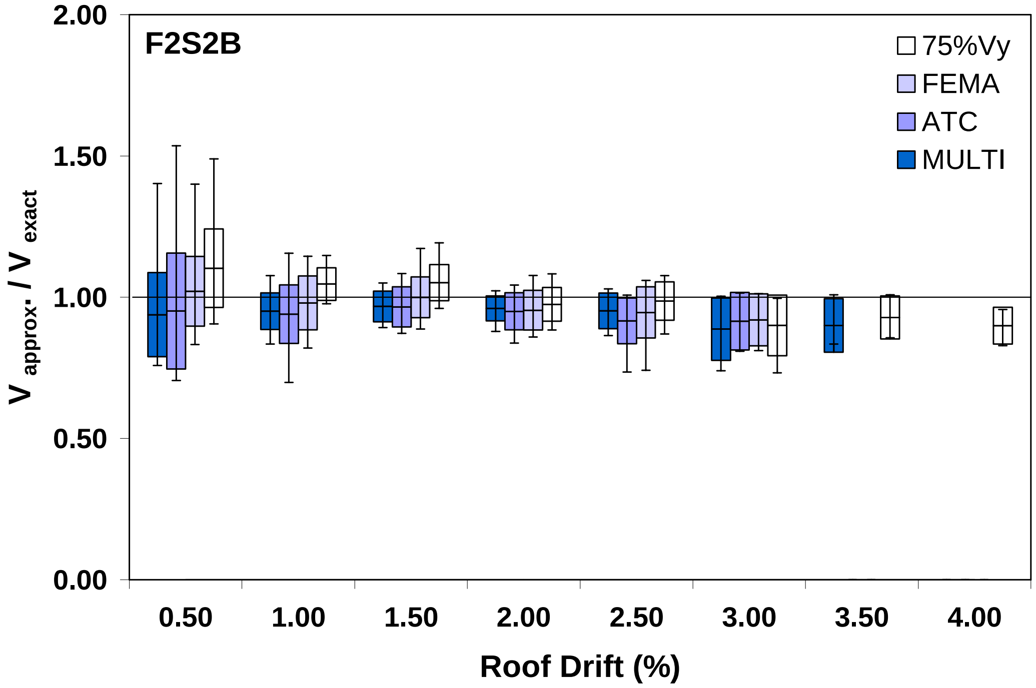


Figure A.6.15 Comparison of Approximations with respect to ‘EXACT’ Values of Maximum Base Shear at Specified Global Roof Drifts for Frame ‘F2S2B’

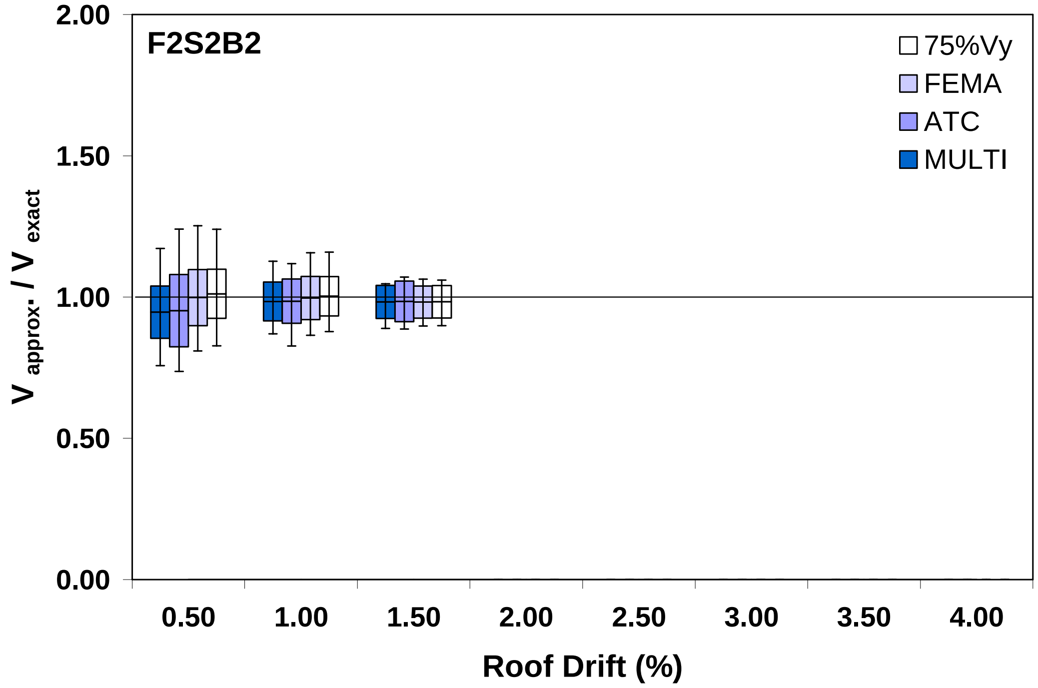


Figure A.6.16 Comparison of Approximations with respect to ‘EXACT’ Values of Maximum Base Shear at Specified Global Roof Drifts for Frame ‘F2S2B2’

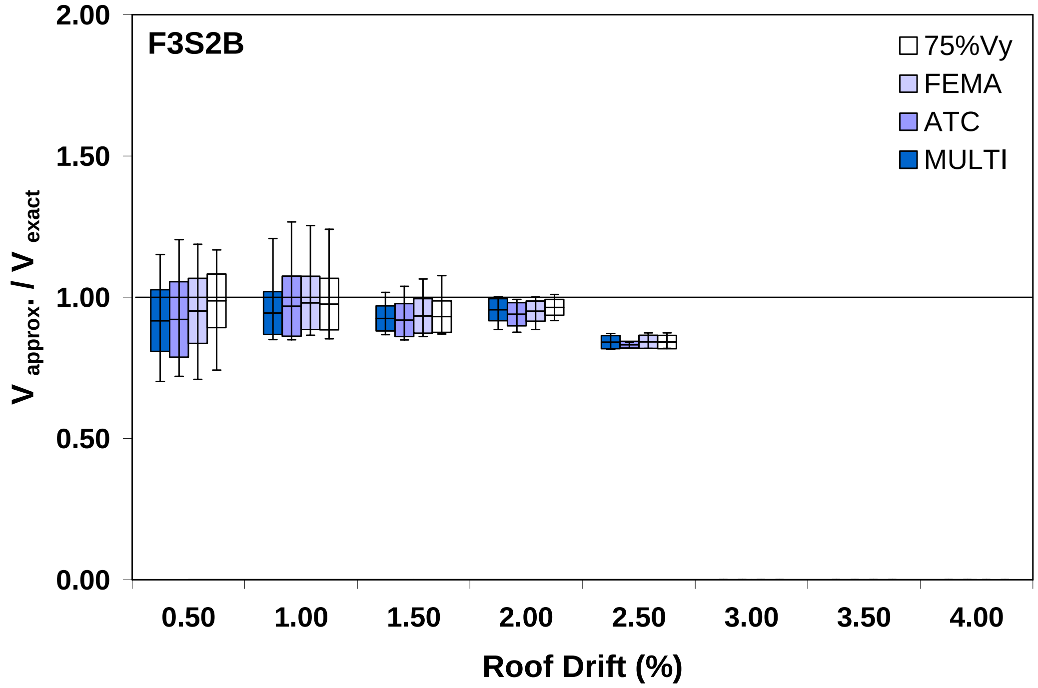


Figure A.6.17 Comparison of Approximations with respect to ‘EXACT’ Values of Maximum Base Shear at Specified Global Roof Drifts for Frame ‘F3S2B’

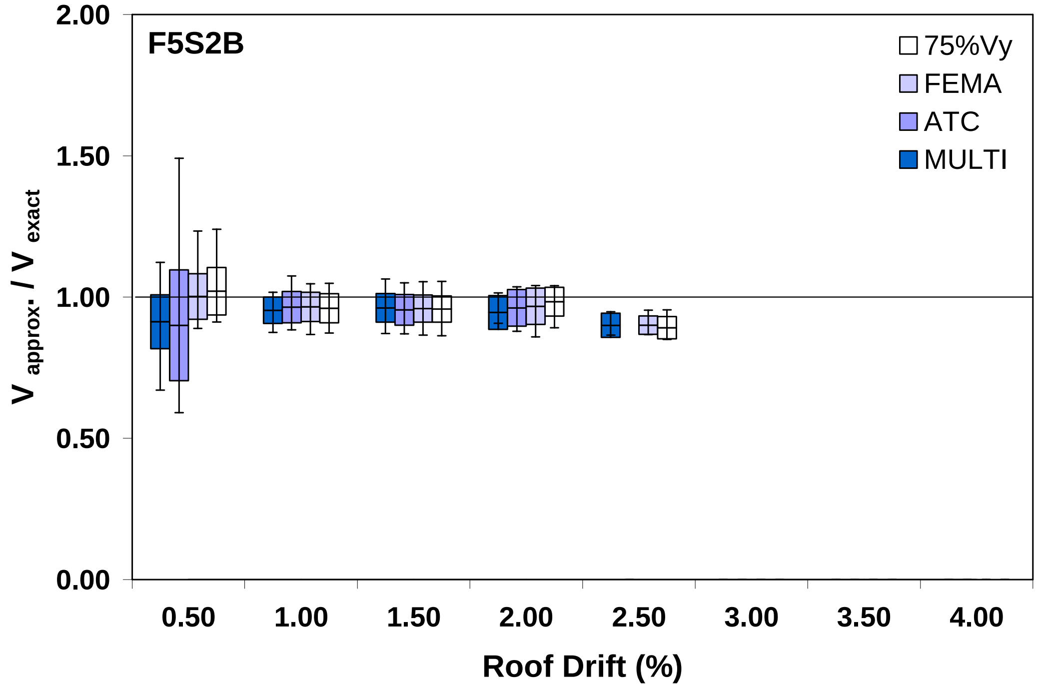


Figure A.6.18 Comparison of Approximations with respect to 'EXACT' Values of Maximum Base Shear at Specified Global Roof Drifts for Frame 'F5S2B'

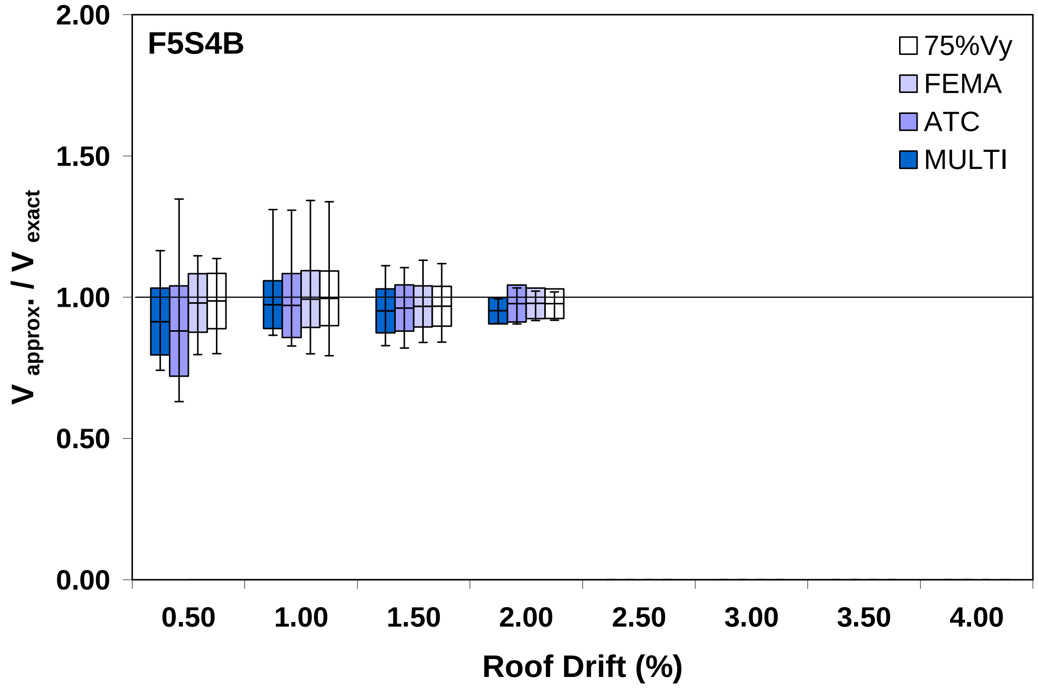


Figure A.6.19 Comparison of Approximations with respect to 'EXACT' Values of Maximum Base Shear at Specified Global Roof Drifts for Frame 'F5S4B'

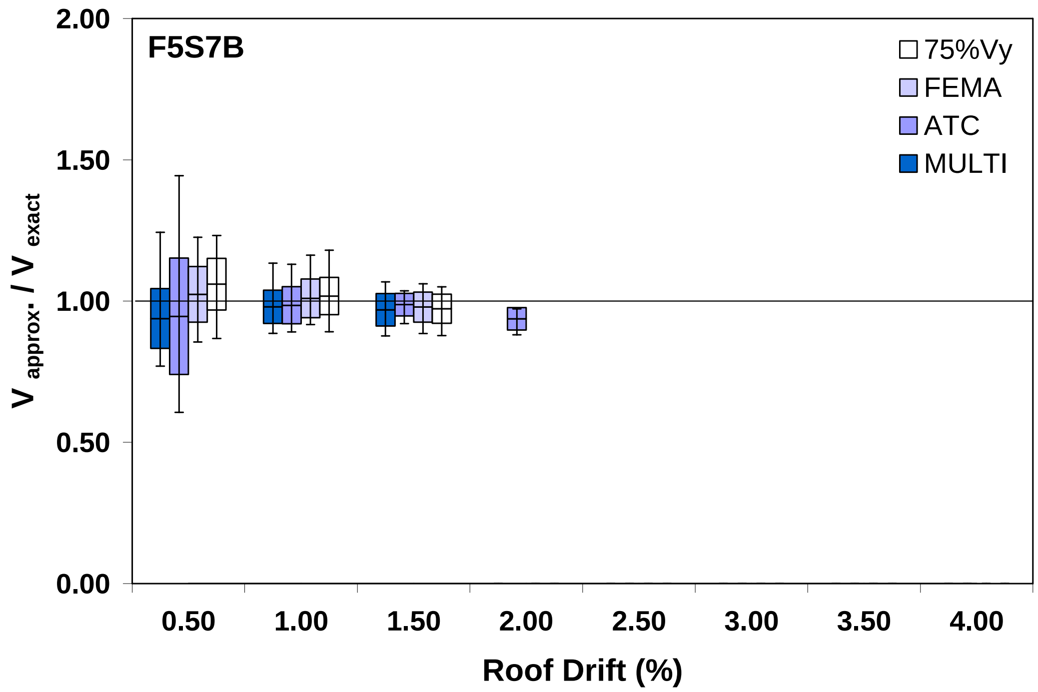


Figure A.6.20 Comparison of Approximations with respect to 'EXACT' Values of Maximum Base Shear at Specified Global Roof Drifts for Frame 'F5S7B'

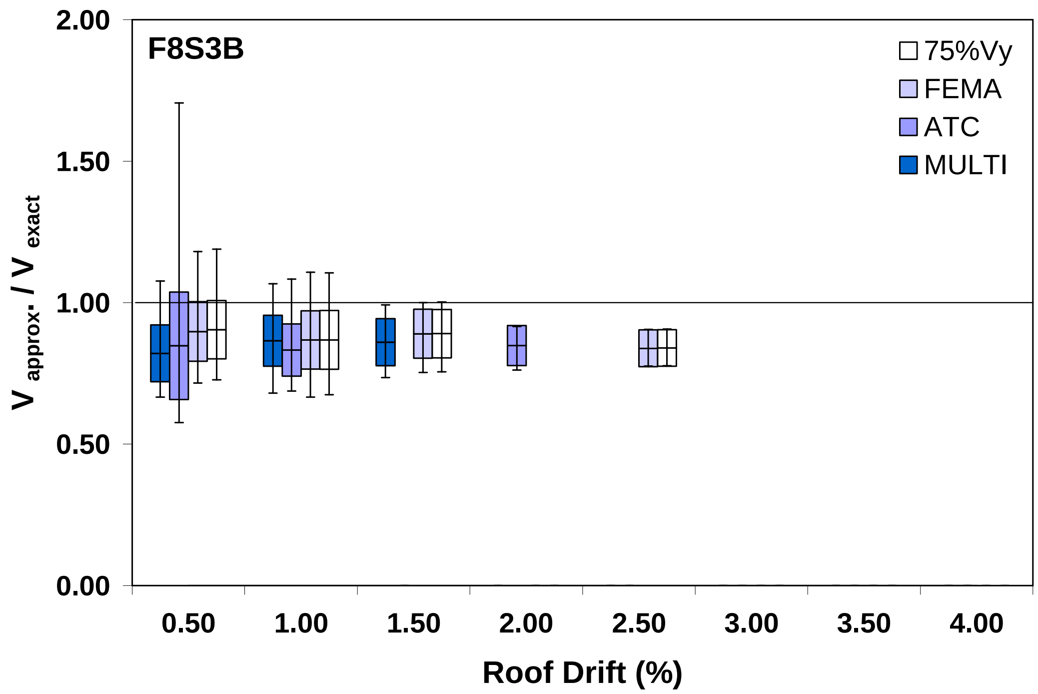


Figure A.6.21 Comparison of Approximations with respect to 'EXACT' Values of Maximum Base Shear at Specified Global Roof Drifts for Frame 'F8S3B'

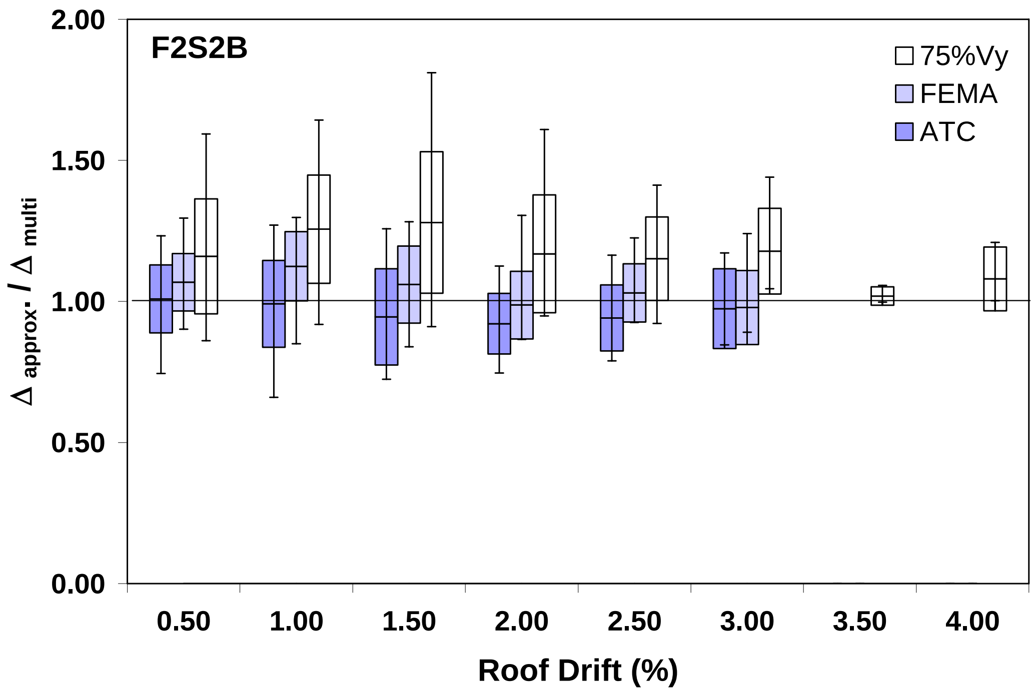


Figure A.6.22 Comparison of Approximations with respect to ‘MULTI’ Values of Maximum Top Displacement at Specified Global Roof Drifts for Frame ‘F2S2B’

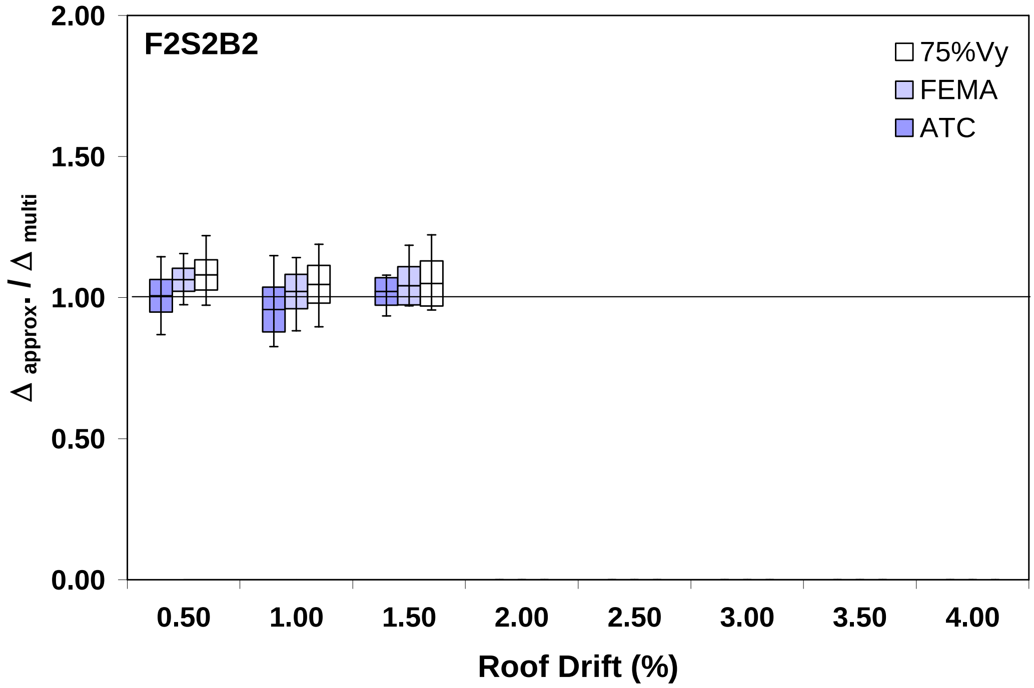


Figure A.6.23 Comparison of Approximations with respect to ‘MULTI’ Values of Maximum Top Displacement at Specified Global Roof Drifts for Frame ‘F2S2B2’

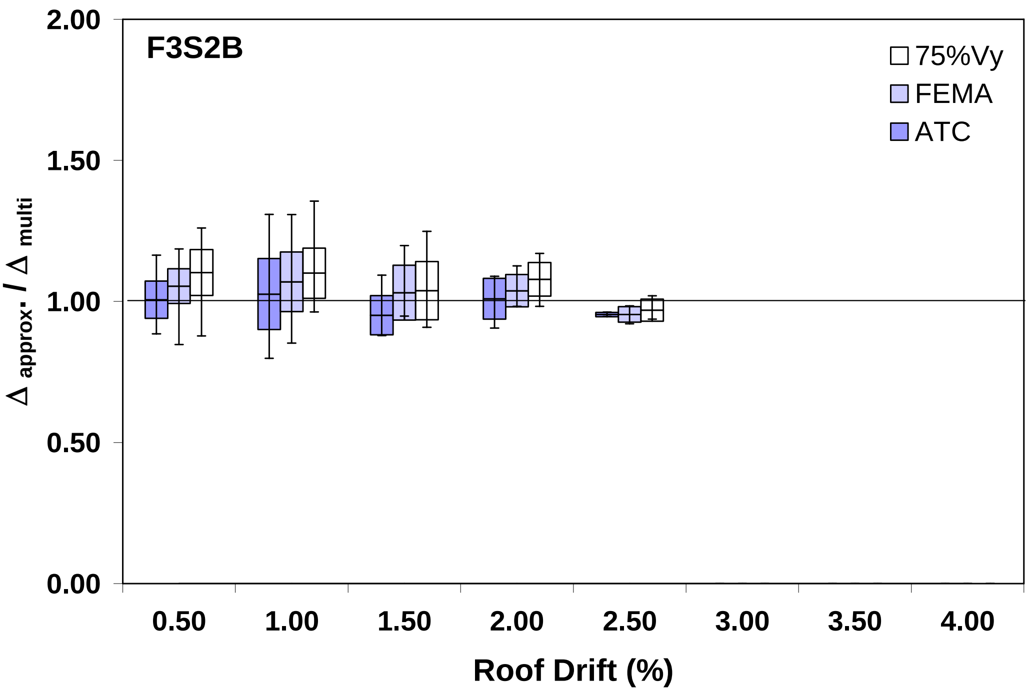


Figure A.6.24 Comparison of Approximations with respect to 'MULTI' Values of Maximum Top Displacement at Specified Global Roof Drifts for Frame 'F3S2B'

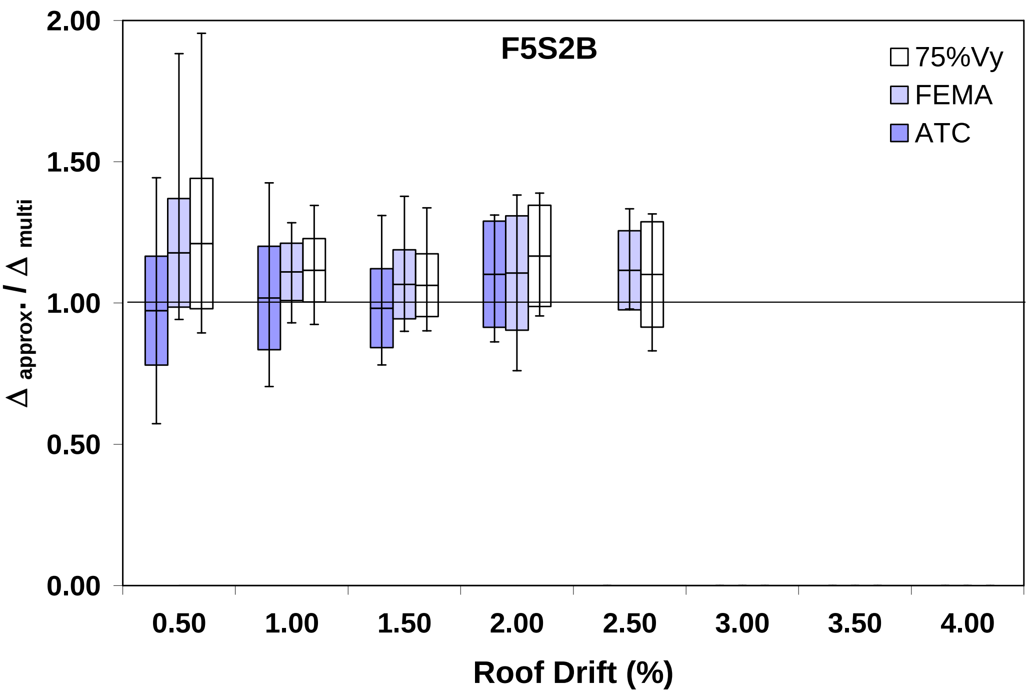


Figure A.6.25 Comparison of Approximations with respect to 'MULTI' Values of Maximum Top Displacement at Specified Global Roof Drifts for Frame 'F5S2B'

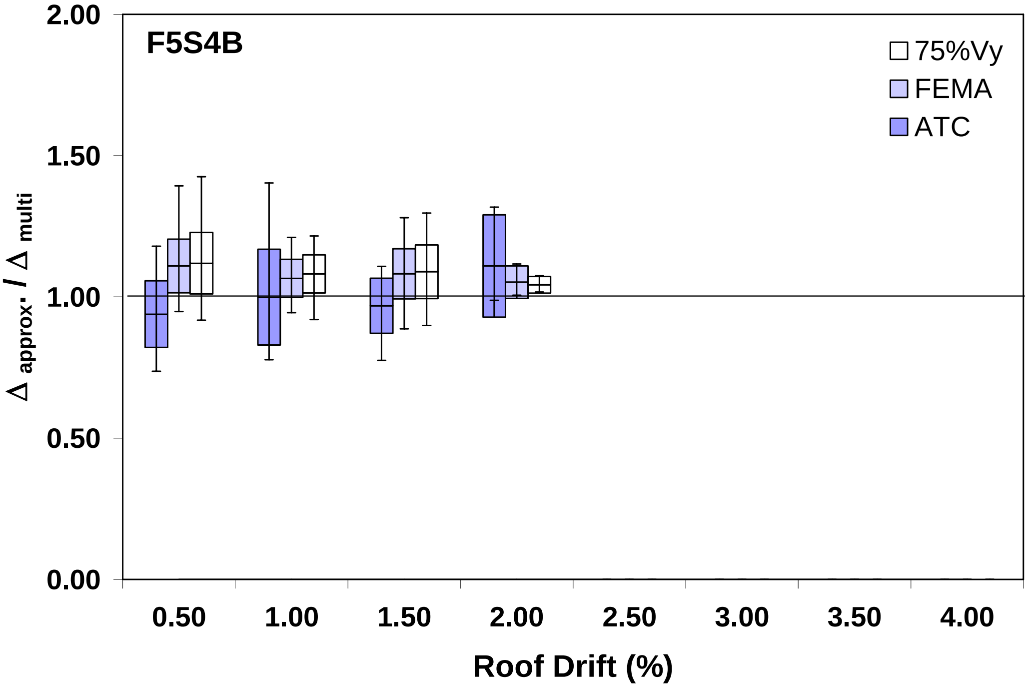


Figure A.6.26 Comparison of Approximations with respect to ‘MULTI’ Values of Maximum Top Displacement at Specified Global Roof Drifts for Frame ‘F5S4B’

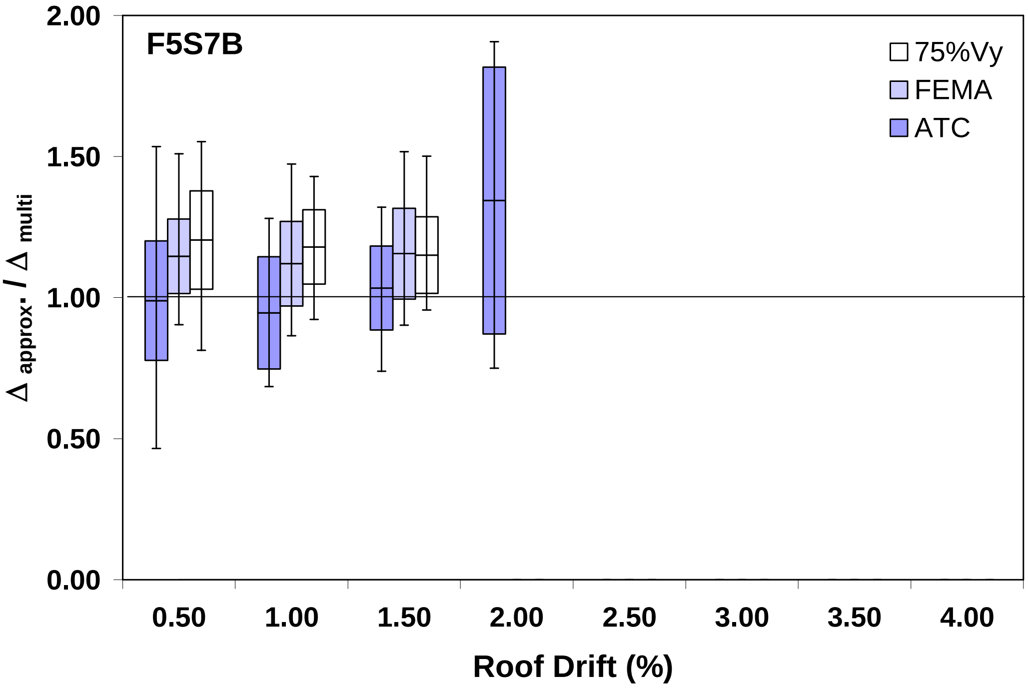


Figure A.6.27 Comparison of Approximations with respect to ‘MULTI’ Values of Maximum Top Displacement at Specified Global Roof Drifts for Frame ‘F5S7B’

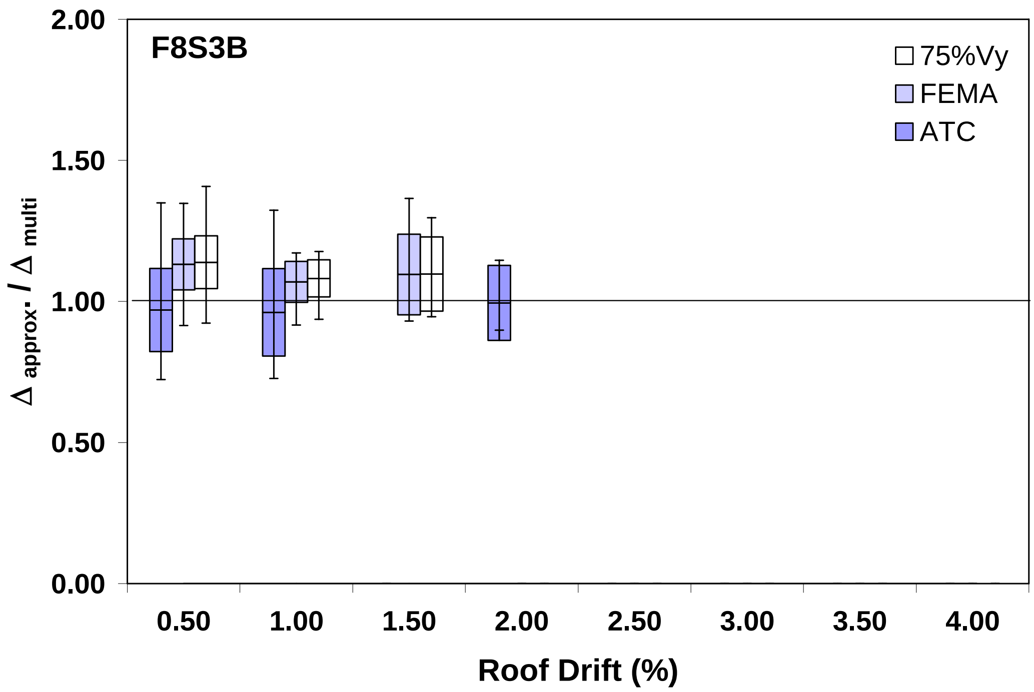


Figure A.6.28 Comparison of Approximations with respect to 'MULTI' Values of Maximum Top Displacement at Specified Global Roof Drifts for Frame 'F8S3B'

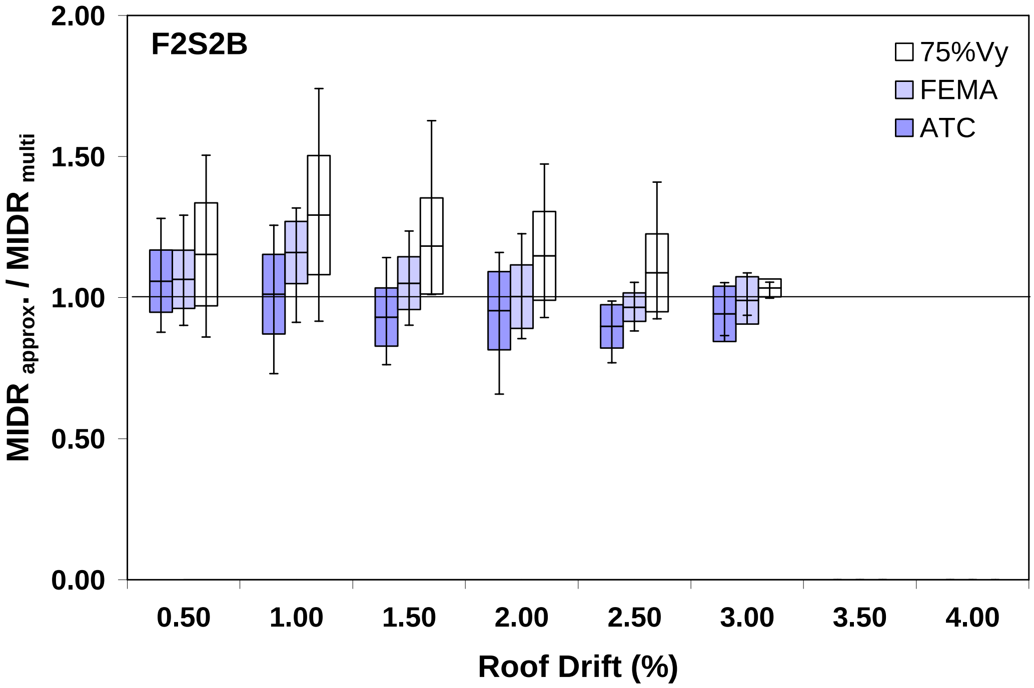


Figure A.6.29 Comparison of Approximations with respect to 'MULTI' Values of Maximum Inter-Story Drift Ratio at Specified Global Roof Drifts for Frame 'F2S2B'

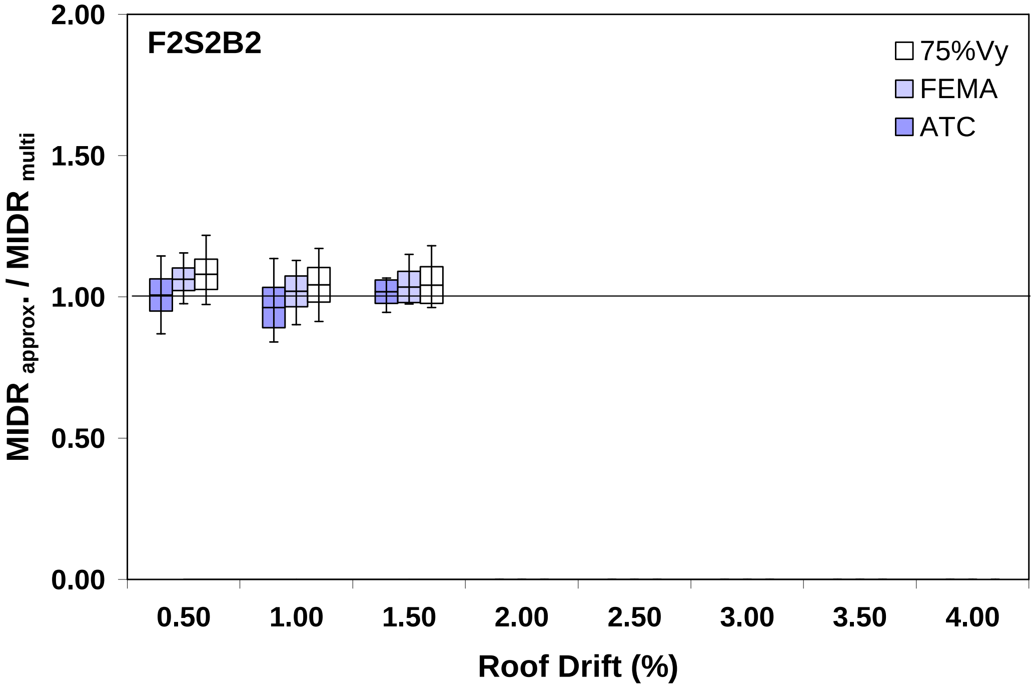


Figure A.6.30 Comparison of Approximations with respect to 'MULTI' Values of Maximum Inter-Story Drift Ratio at Specified Global Roof Drifts for Frame 'F2S2B2'

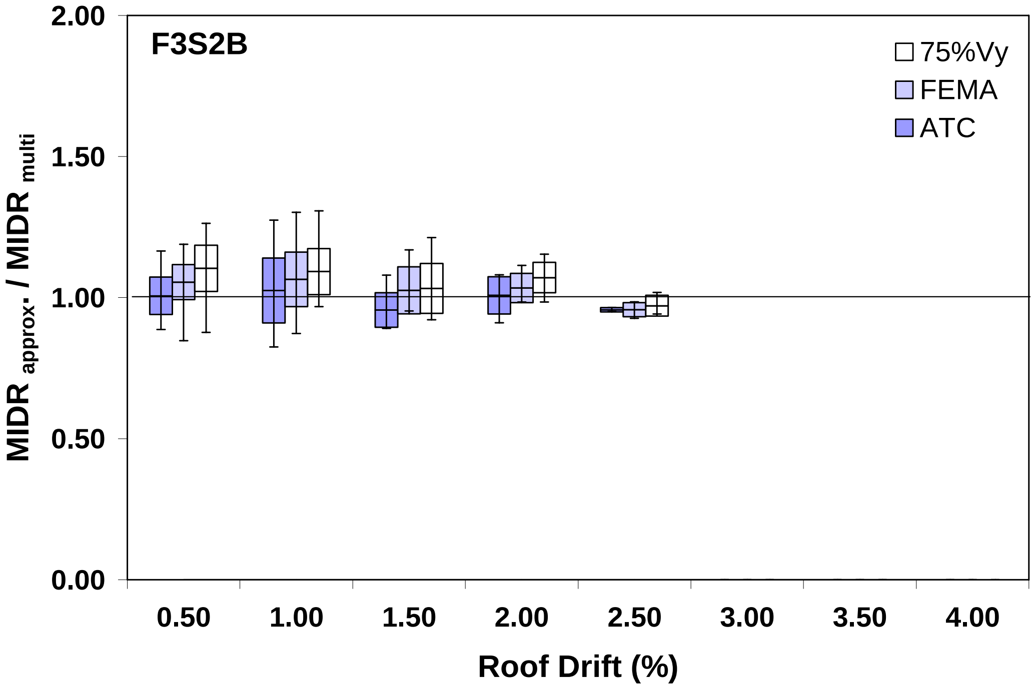


Figure A.6.31 Comparison of Approximations with respect to 'MULTI' Values of Maximum Inter-Story Drift Ratio at Specified Global Roof Drifts for Frame 'F3S2B'

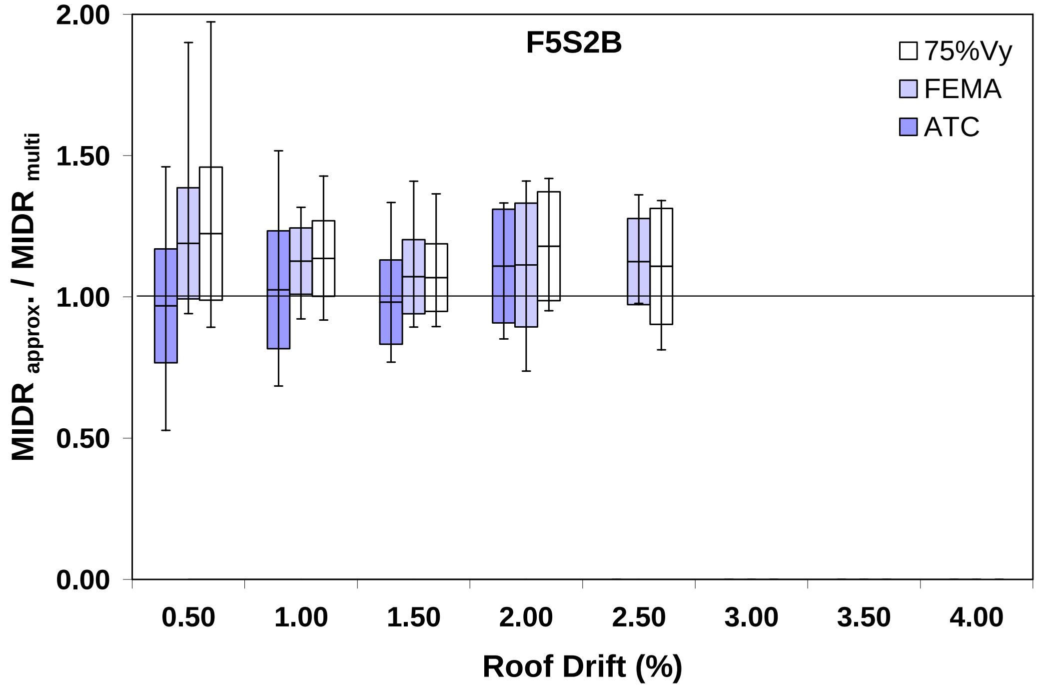


Figure A.6.32 Comparison of Approximations with respect to 'MULTI' Values of Maximum Inter-Story Drift Ratio at Specified Global Roof Drifts for Frame 'F5S2B'

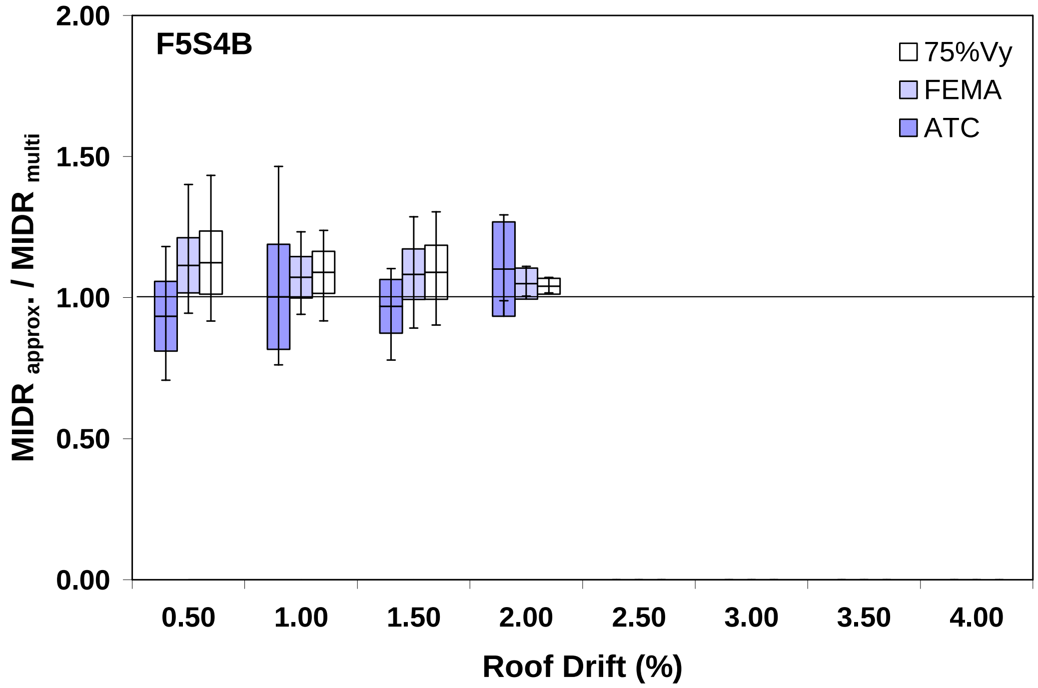


Figure A.6.33 Comparison of Approximations with respect to 'MULTI' Values of Maximum Inter-Story Drift Ratio at Specified Global Roof Drifts for Frame 'F5S4B'

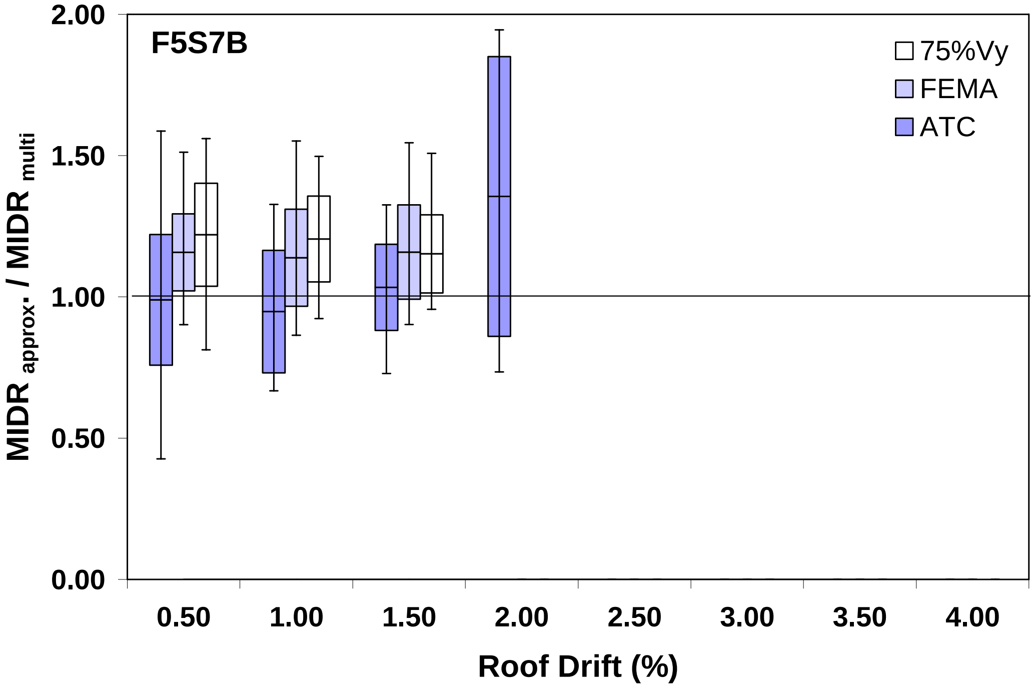


Figure A.6.34 Comparison of Approximations with respect to 'MULTI' Values of Maximum Inter-Story Drift Ratio at Specified Global Roof Drifts for Frame 'F5S7B'

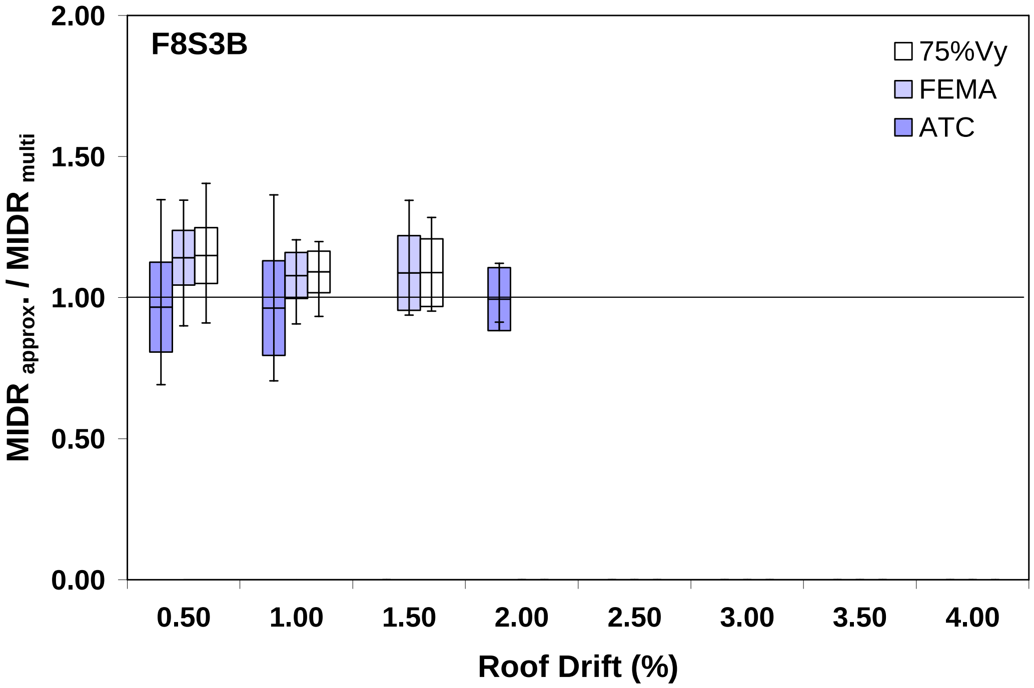


Figure A.6.35 Comparison of Approximations with respect to 'MULTI' Values of Maximum Inter-Story Drift Ratio at Specified Global Roof Drifts for Frame 'F8S3B'

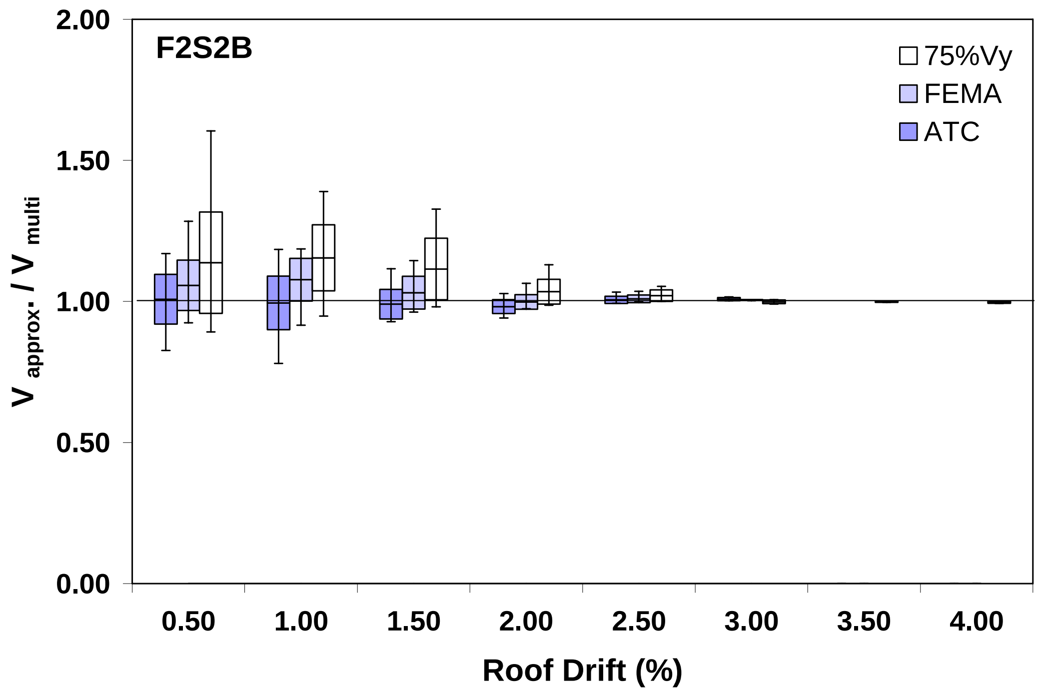


Figure A.6.36 Comparison of Approximations with respect to ‘MULTI’ Values of Maximum Base Shear at Specified Global Roof Drifts for Frame ‘F2S2B’

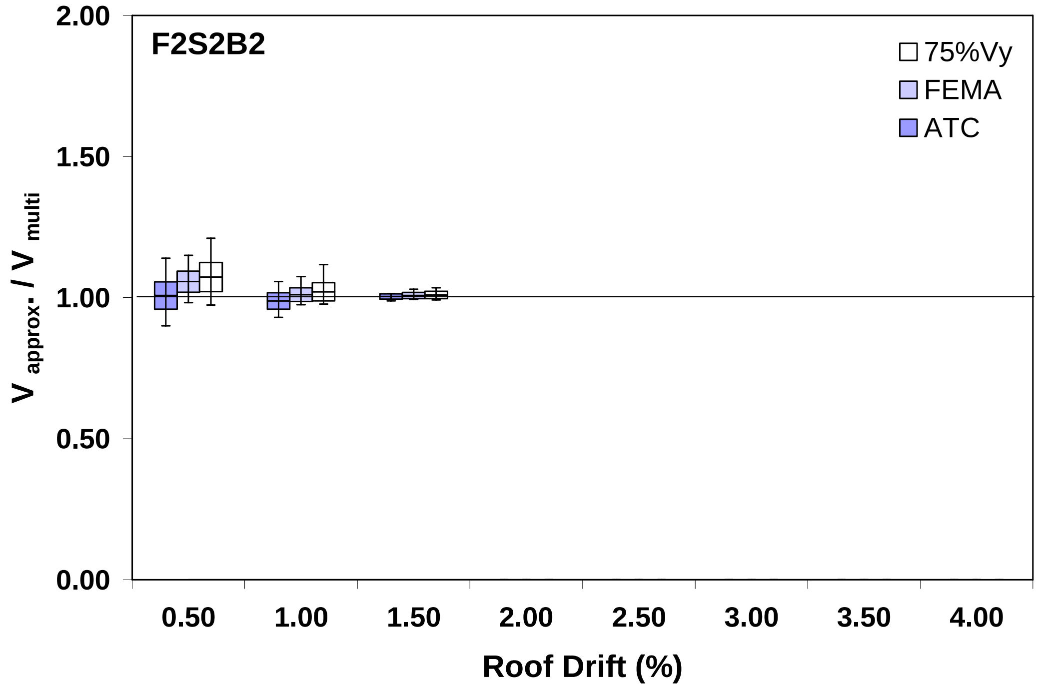


Figure A.6.37 Comparison of Approximations with respect to ‘MULTI’ Values of Maximum Base Shear at Specified Global Roof Drifts for Frame ‘F2S2B2’

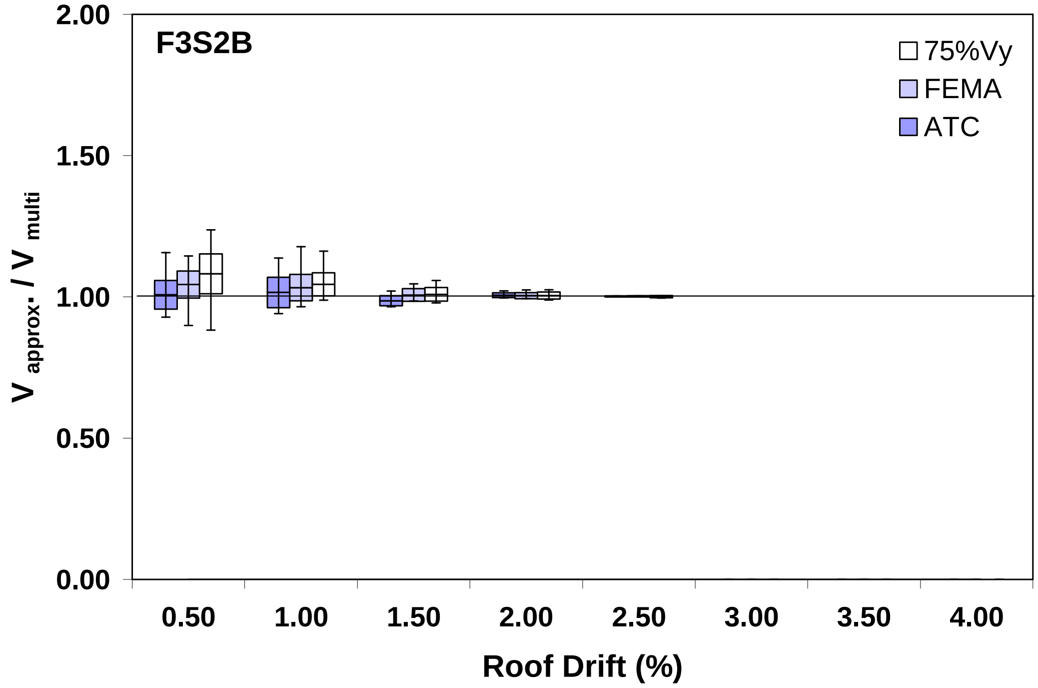


Figure A.6.38 Comparison of Approximations with respect to ‘MULTI’ Values of Maximum Base Shear at Specified Global Roof Drifts for Frame ‘F3S2B’

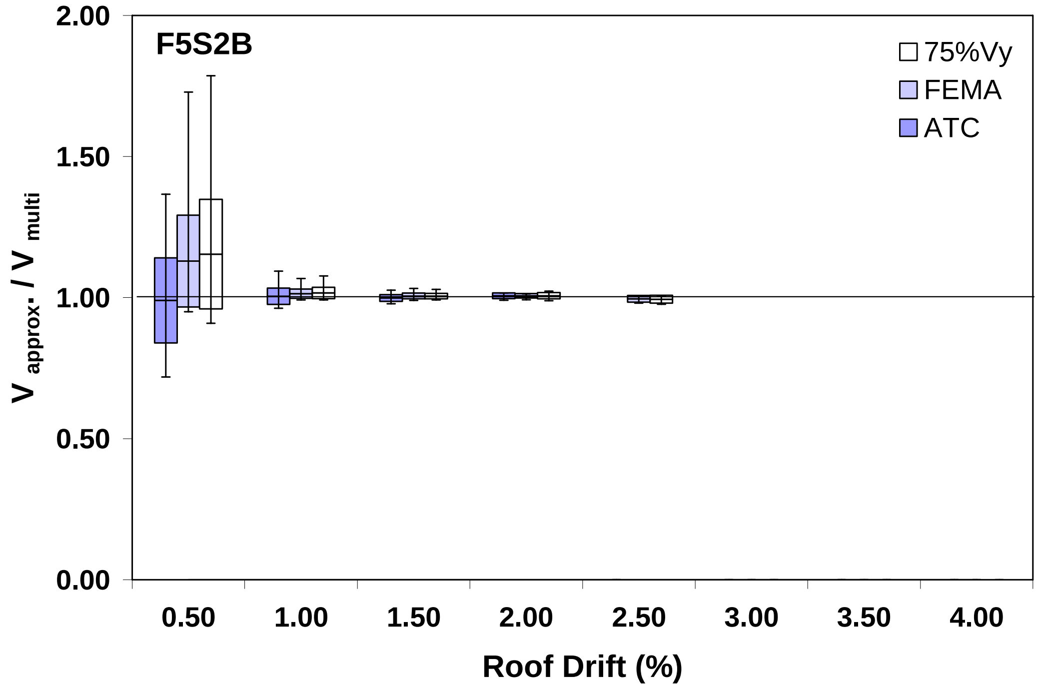


Figure A.6.39 Comparison of Approximations with respect to ‘MULTI’ Values of Maximum Base Shear at Specified Global Roof Drifts for Frame ‘F5S2B’

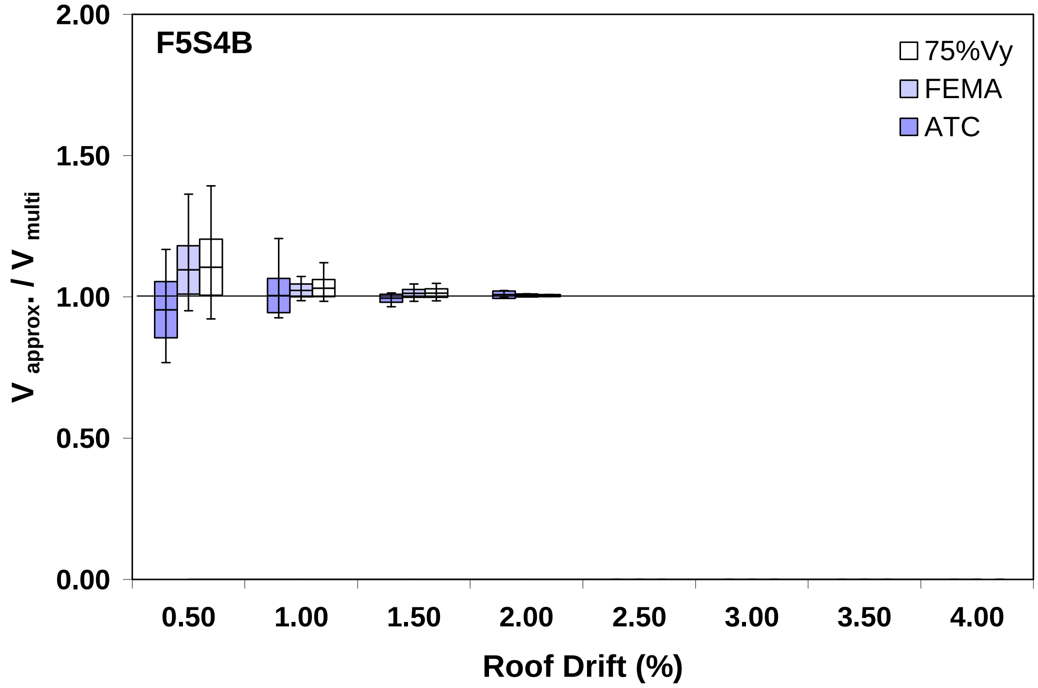


Figure A.6.40 Comparison of Approximations with respect to ‘MULTI’ Values of Maximum Base Shear at Specified Global Roof Drifts for Frame ‘F5S4B’

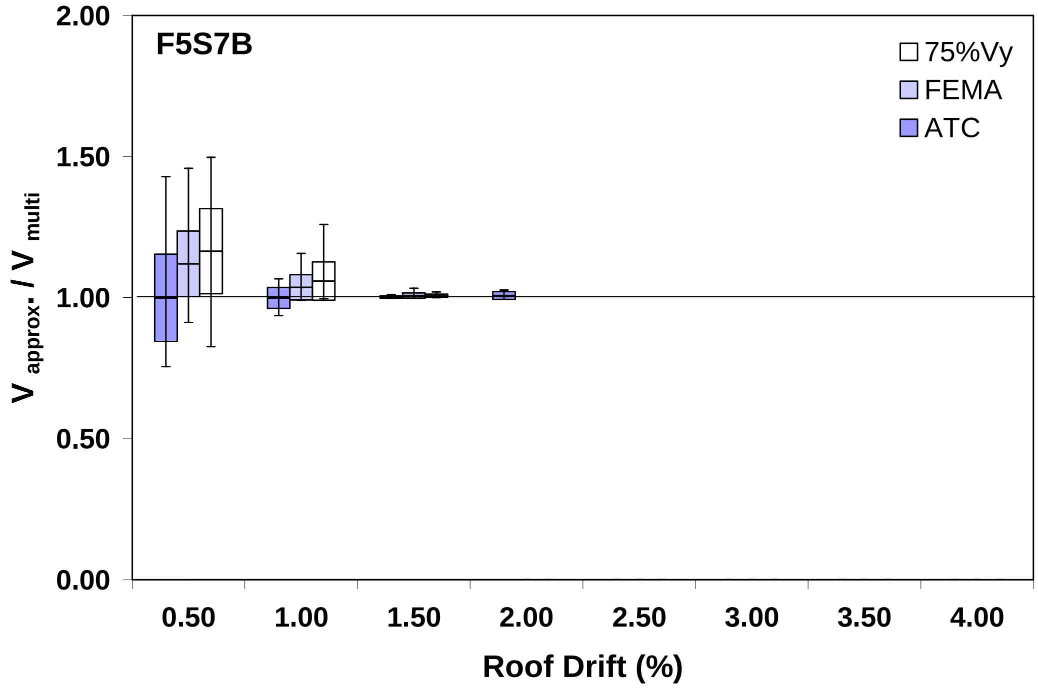


Figure A.6.41 Comparison of Approximations with respect to ‘MULTI’ Values of Maximum Base Shear at Specified Global Roof Drifts for Frame ‘F5S7B’

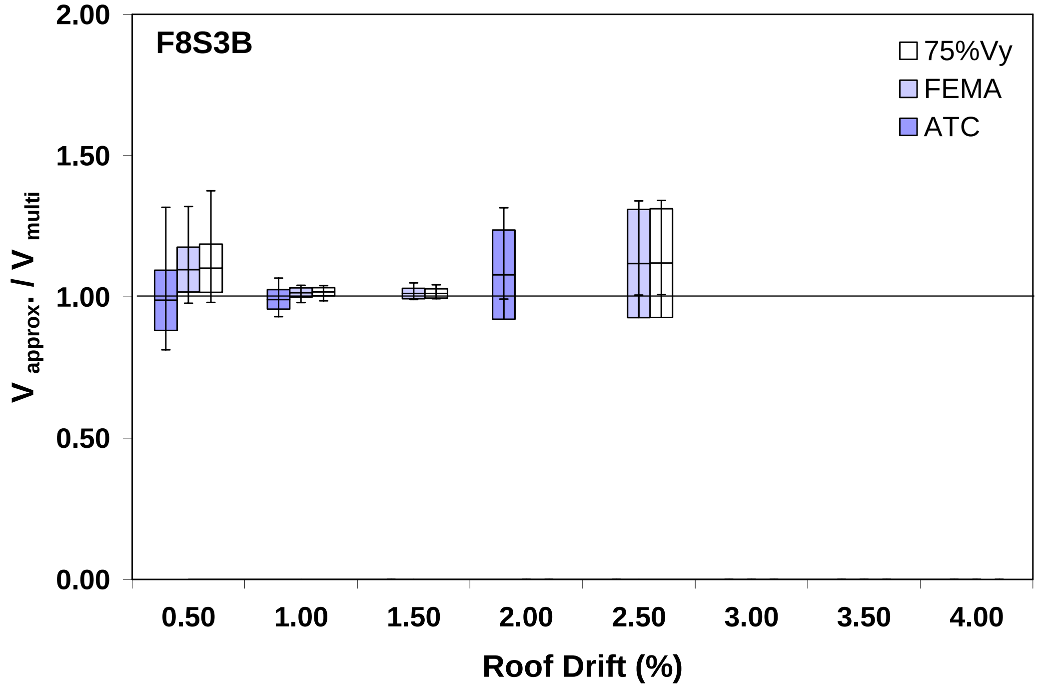


Figure A.6.42 Comparison of Approximations with respect to ‘MULTI’ Values of Maximum Base Shear at Specified Global Roof Drifts for Frame ‘F8S3B’

A.7 DEPENDENCY GRAPHS

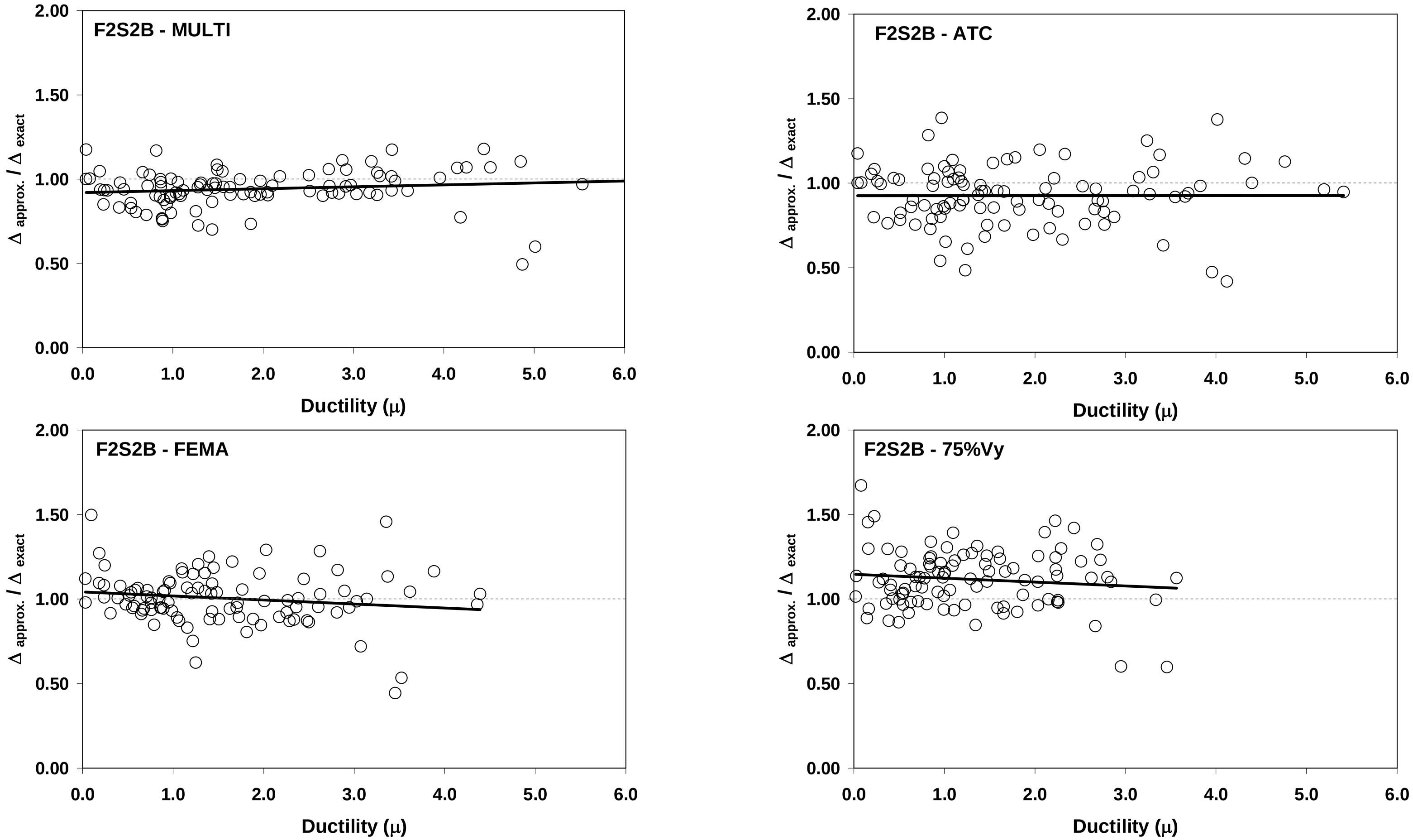


Figure A.7.1 Dependency on Ductility (Frame 'F2S2B' – Maximum Top Displacement)

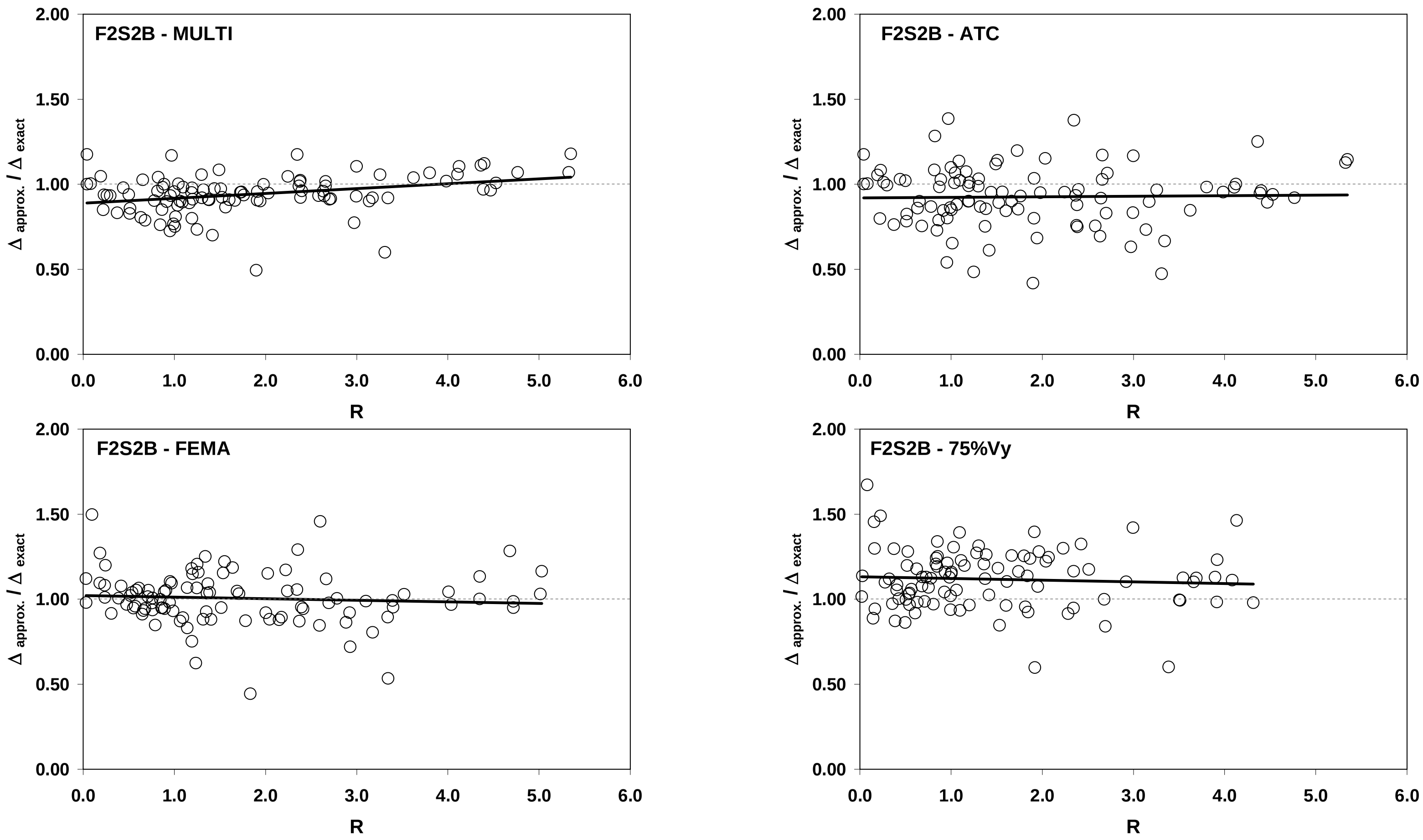


Figure A.7.2 Dependency on Strength Reduction Factor (Frame ‘F2S2B’ – Maximum Top Displacement)

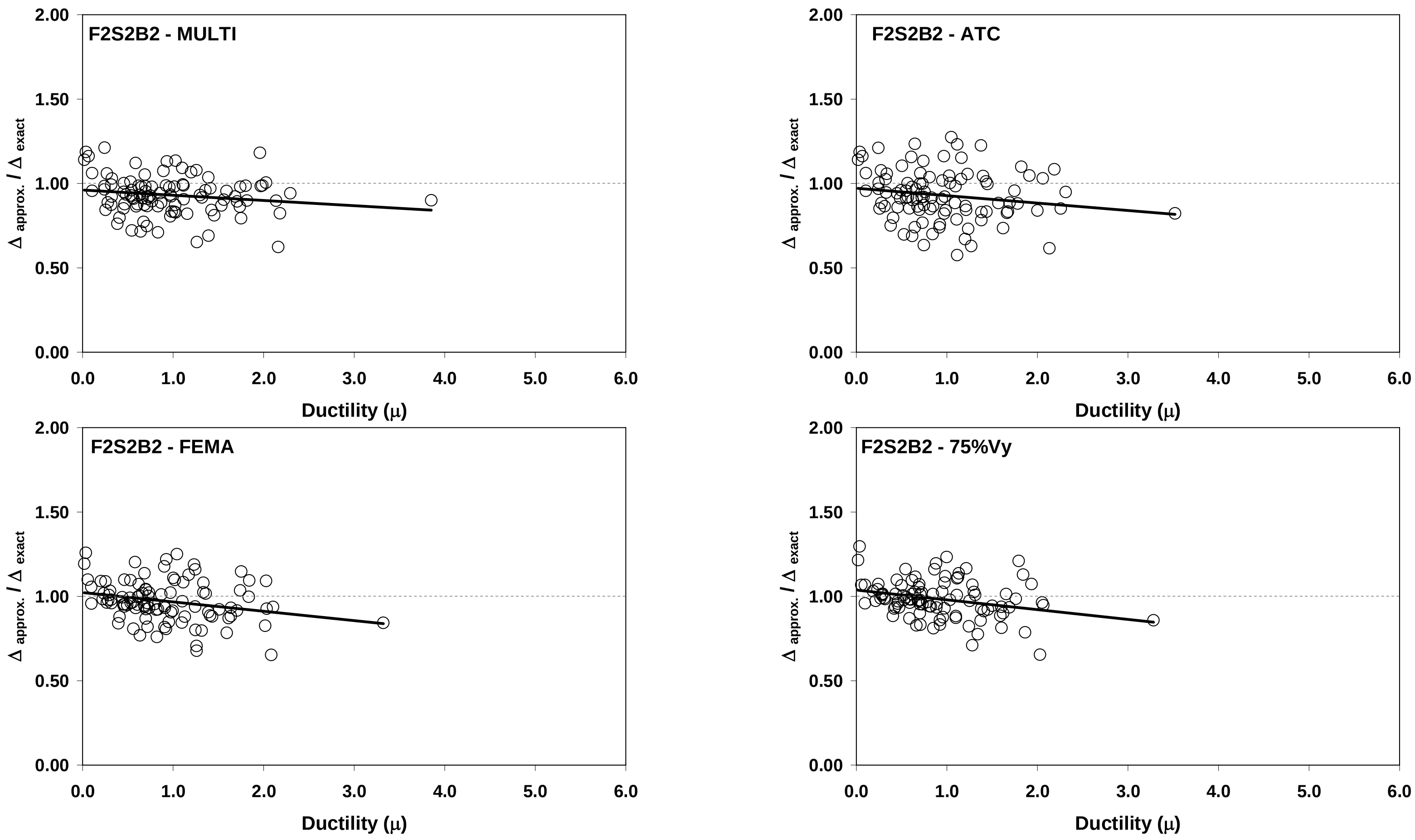


Figure A.7.3 Dependency on Ductility (Frame ‘F2S2B2’ – Maximum Top Displacement)

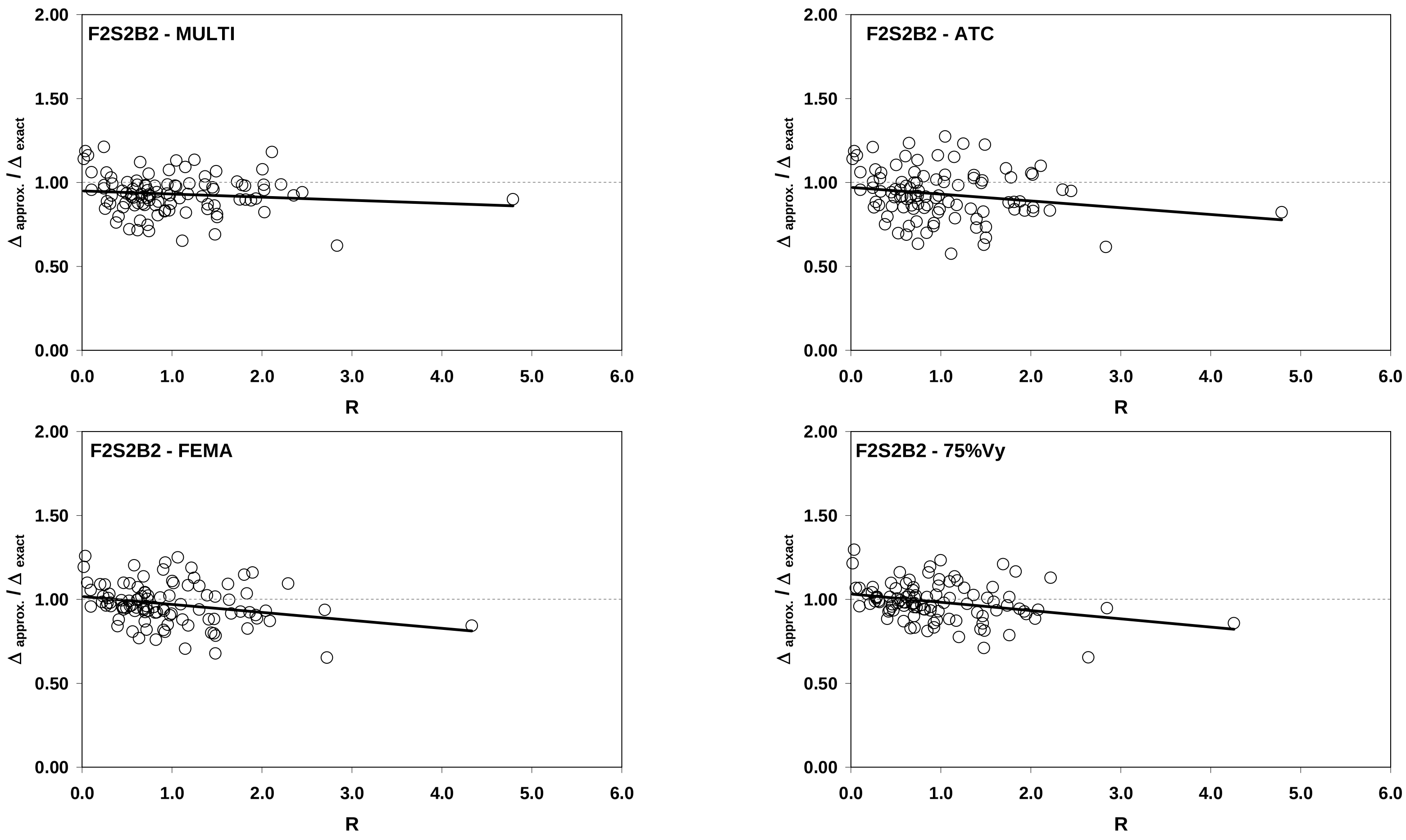


Figure A.7.4 Dependency on Strength Reduction Factor (Frame ‘F2S2B2’ – Maximum Top Displacement)

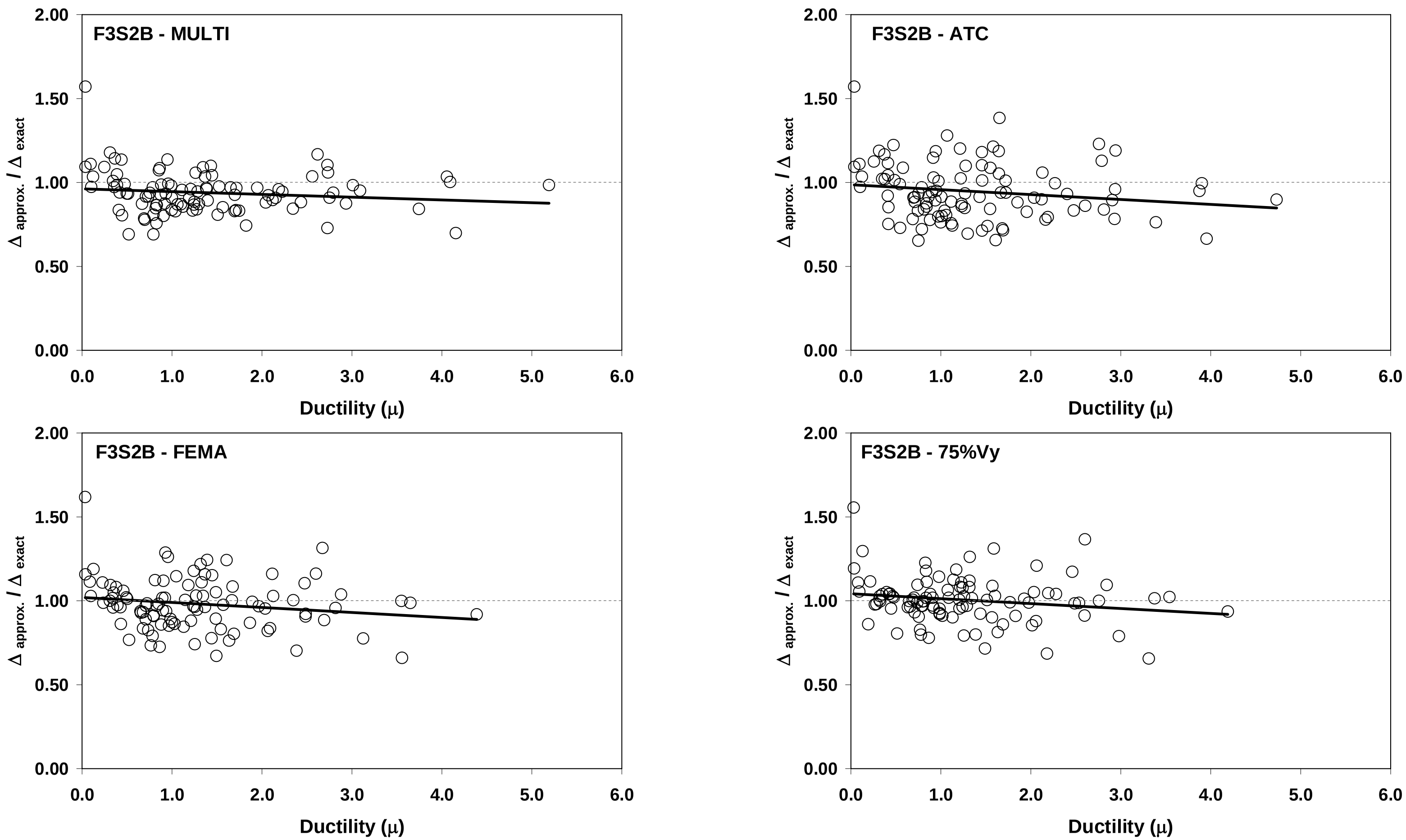


Figure A.7.5 Dependency on Ductility (Frame 'F3S2B' – Maximum Top Displacement)

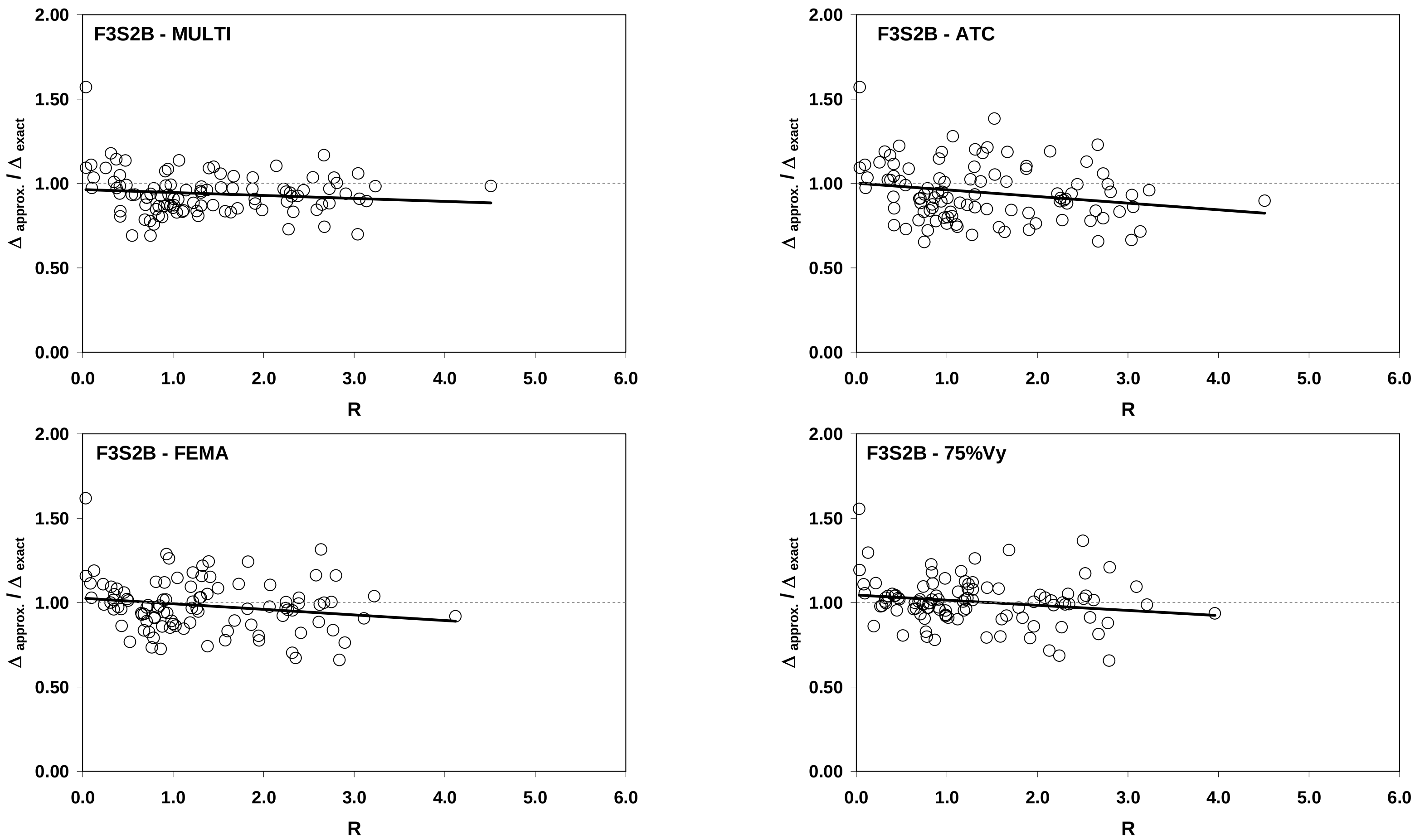


Figure A.7.6 Dependency on Strength Reduction Factor (Frame ‘F3S2B’ – Maximum Top Displacement)

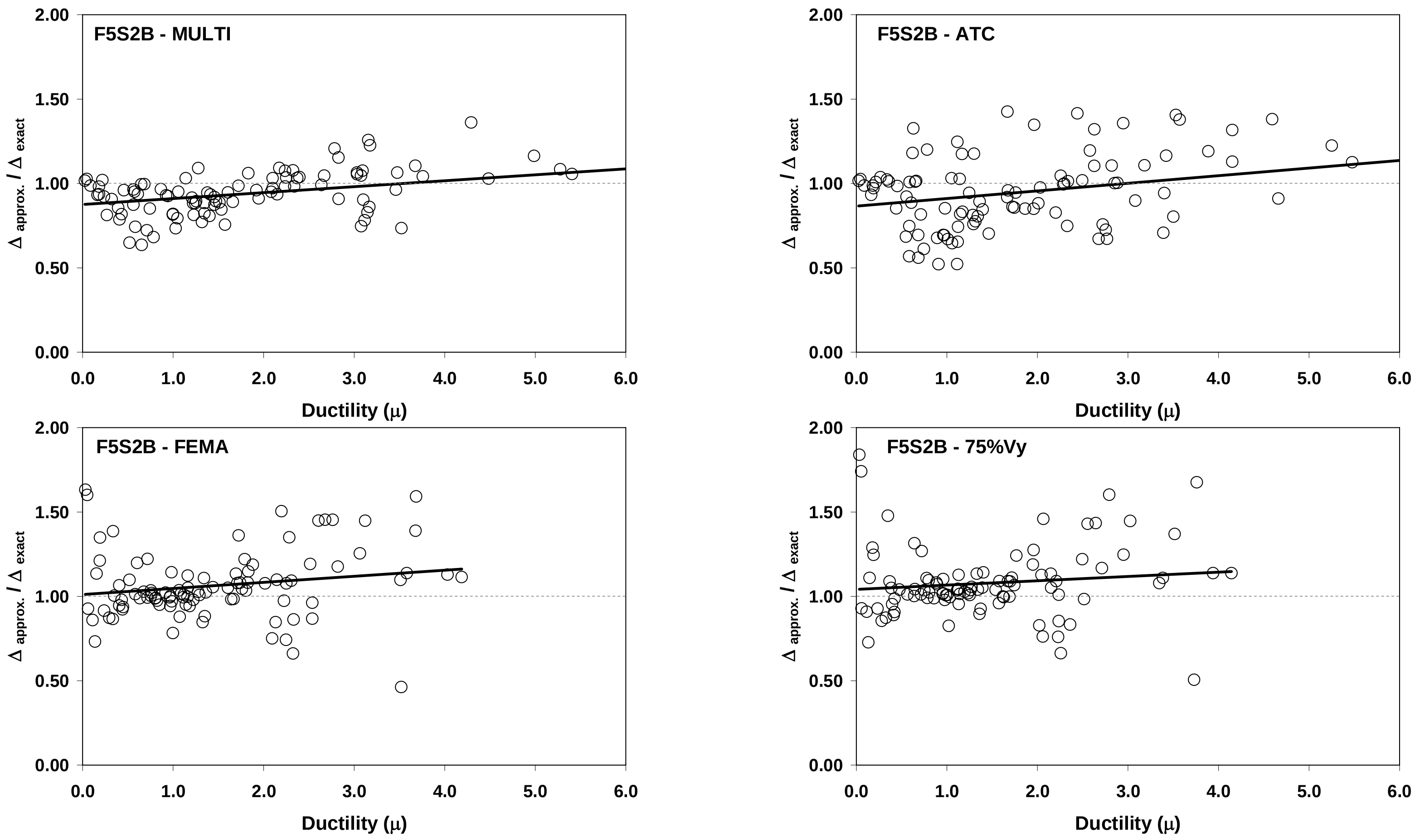


Figure A.7.7 Dependency on Ductility (Frame ‘F5S2B’ – Maximum Top Displacement)

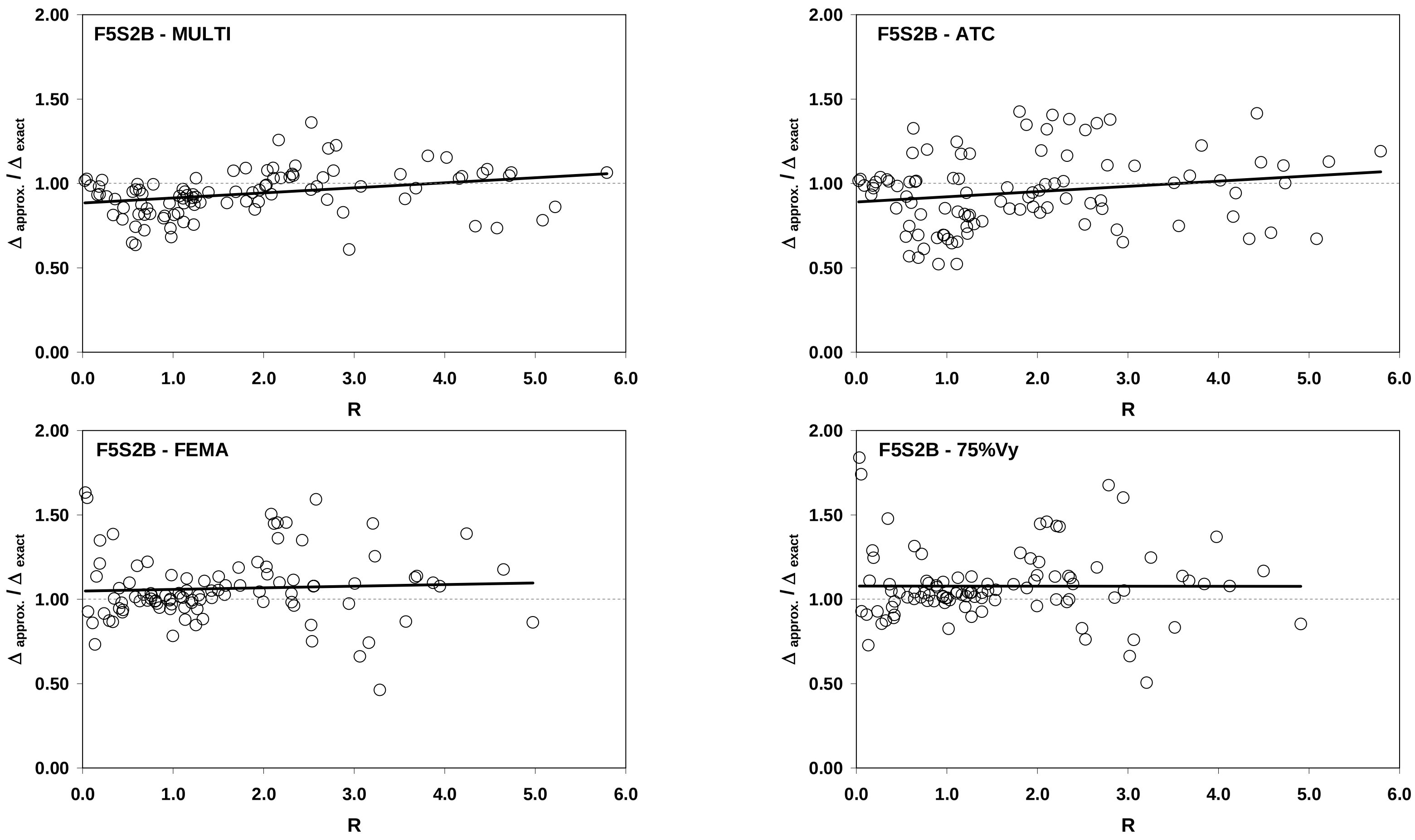


Figure A.7.8 Dependency on Strength Reduction Factor (Frame ‘F5S2B’ – Maximum Top Displacement)

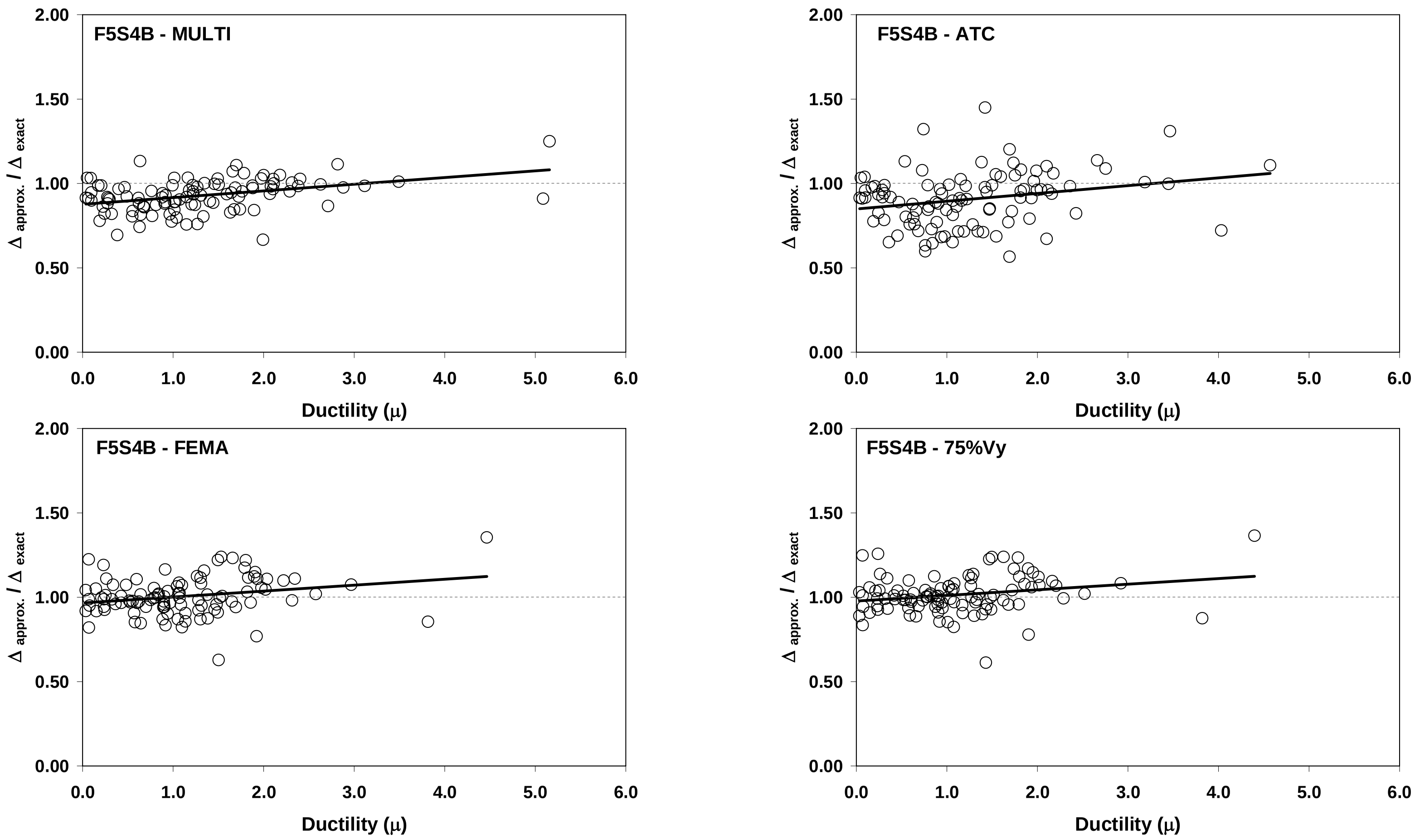


Figure A.7.9 Dependency on Ductility (Frame ‘F5S4B’ – Maximum Top Displacement)

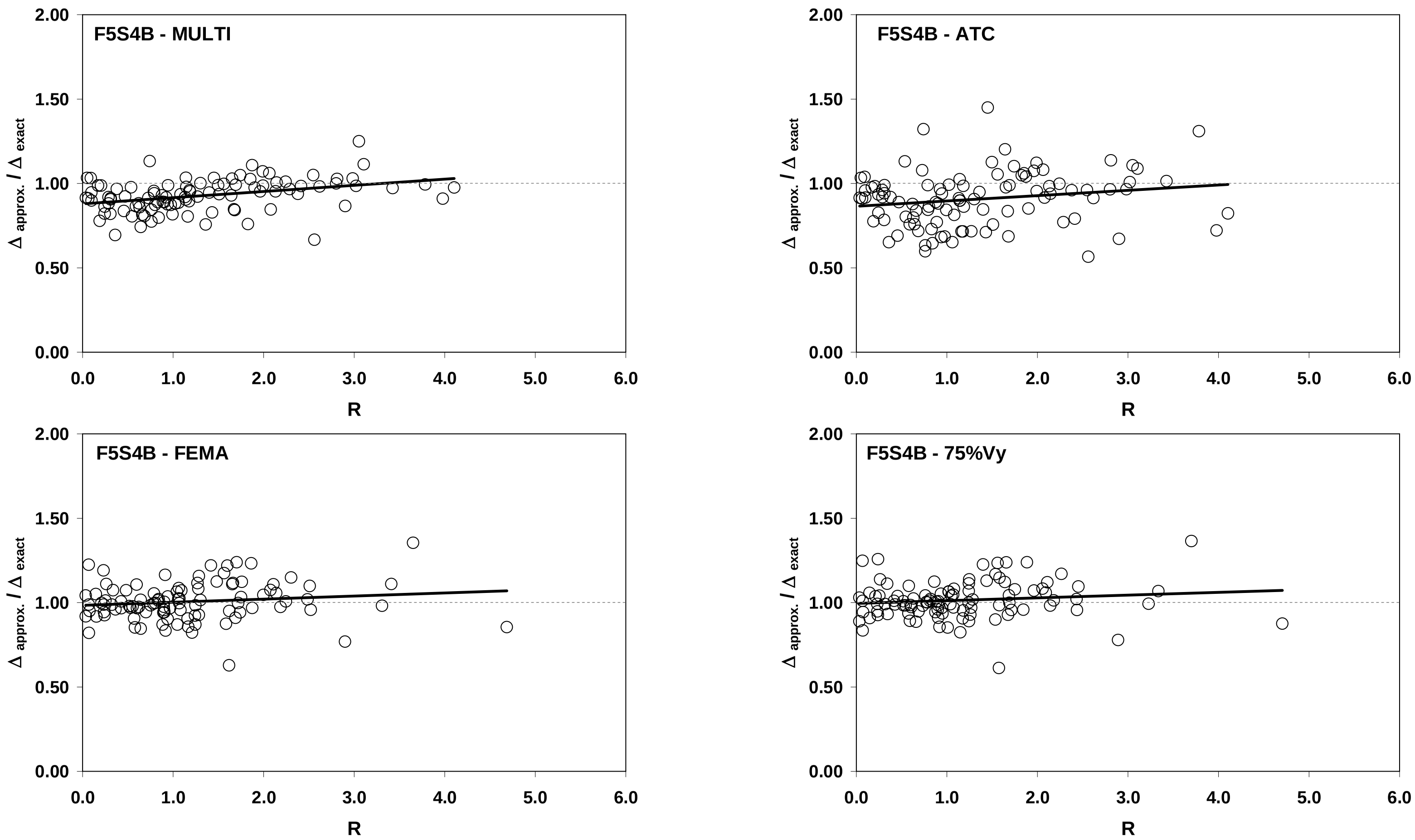


Figure A.7.10 Dependency on Strength Reduction Factor (Frame ‘F5S4B’ – Maximum Top Displacement)

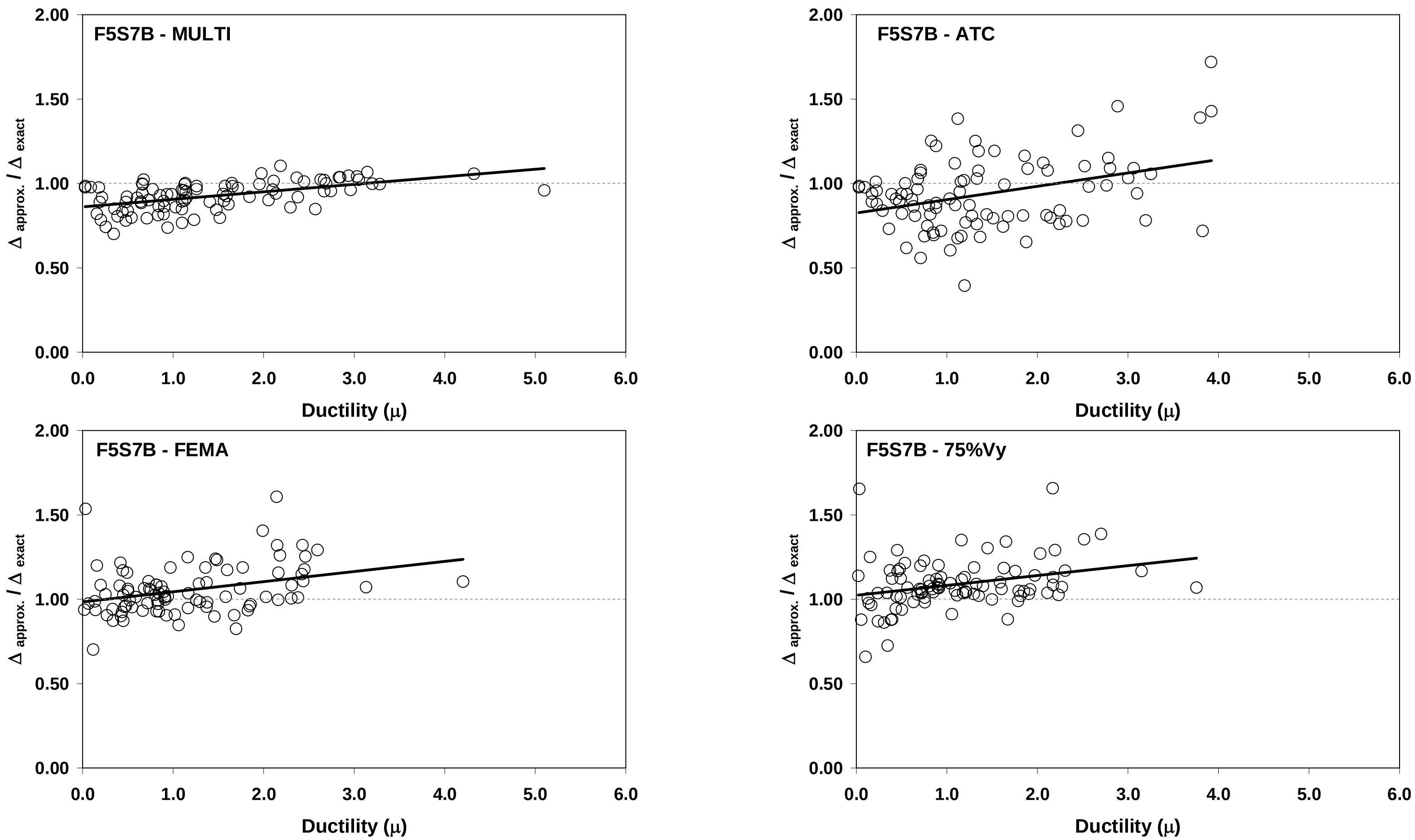


Figure A.7.11 Dependency on Ductility (Frame ‘F5S7B’ – Maximum Top Displacement)

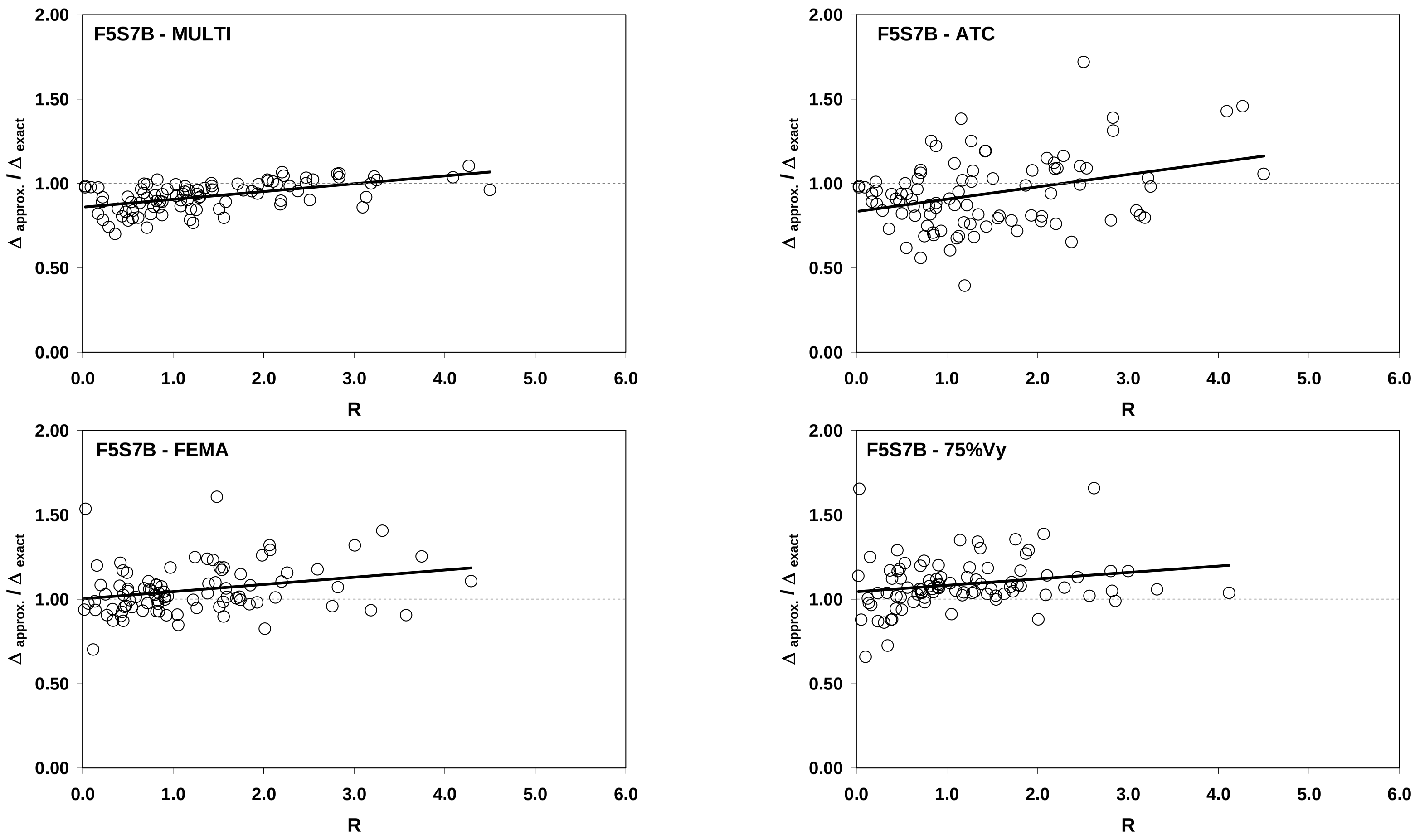


Figure A.7.12 Dependency on Strength Reduction Factor (Frame ‘F5S7B’ – Maximum Top Displacement)

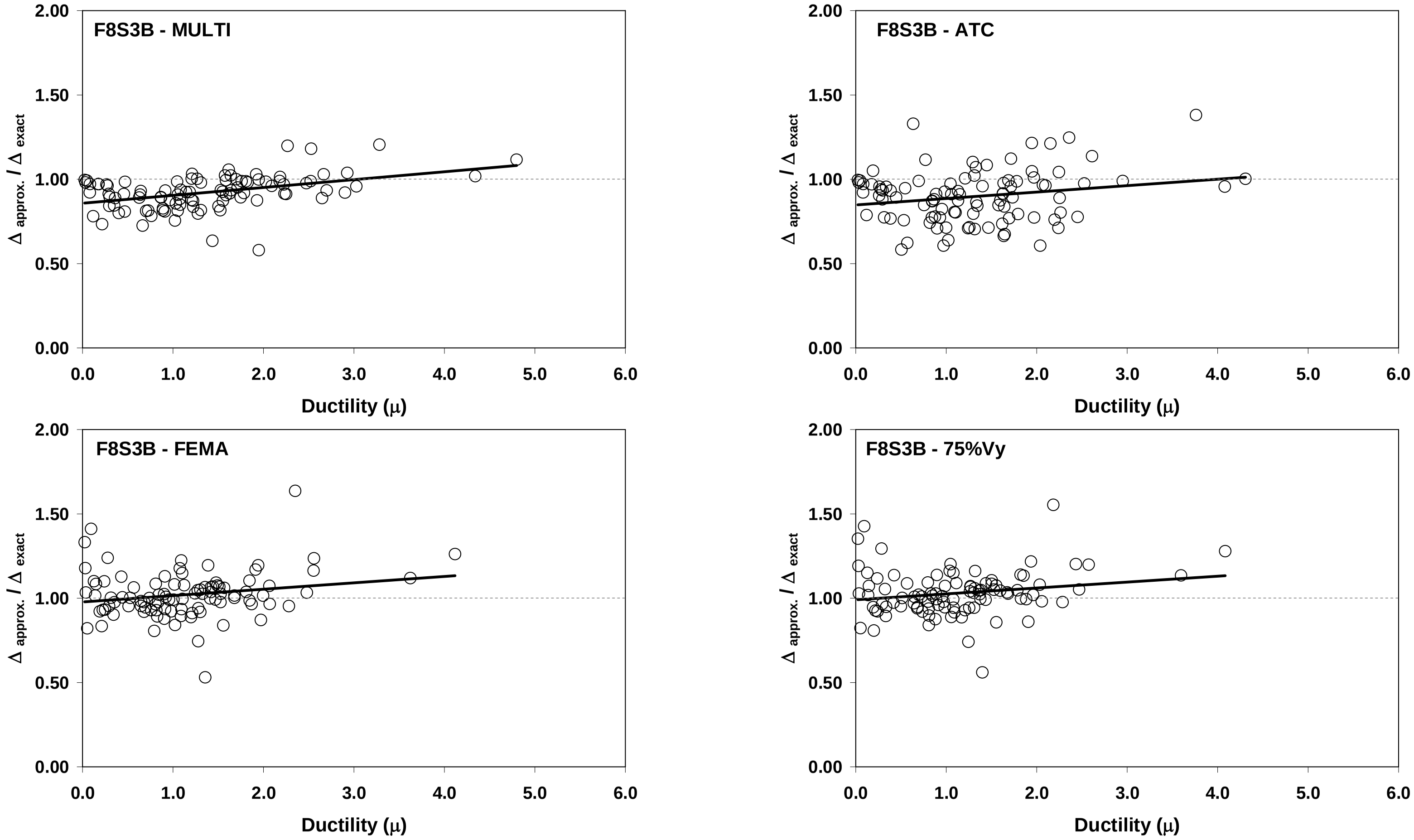


Figure A.7.13 Dependency on Ductility (Frame ‘F8S3B’ – Maximum Top Displacement)

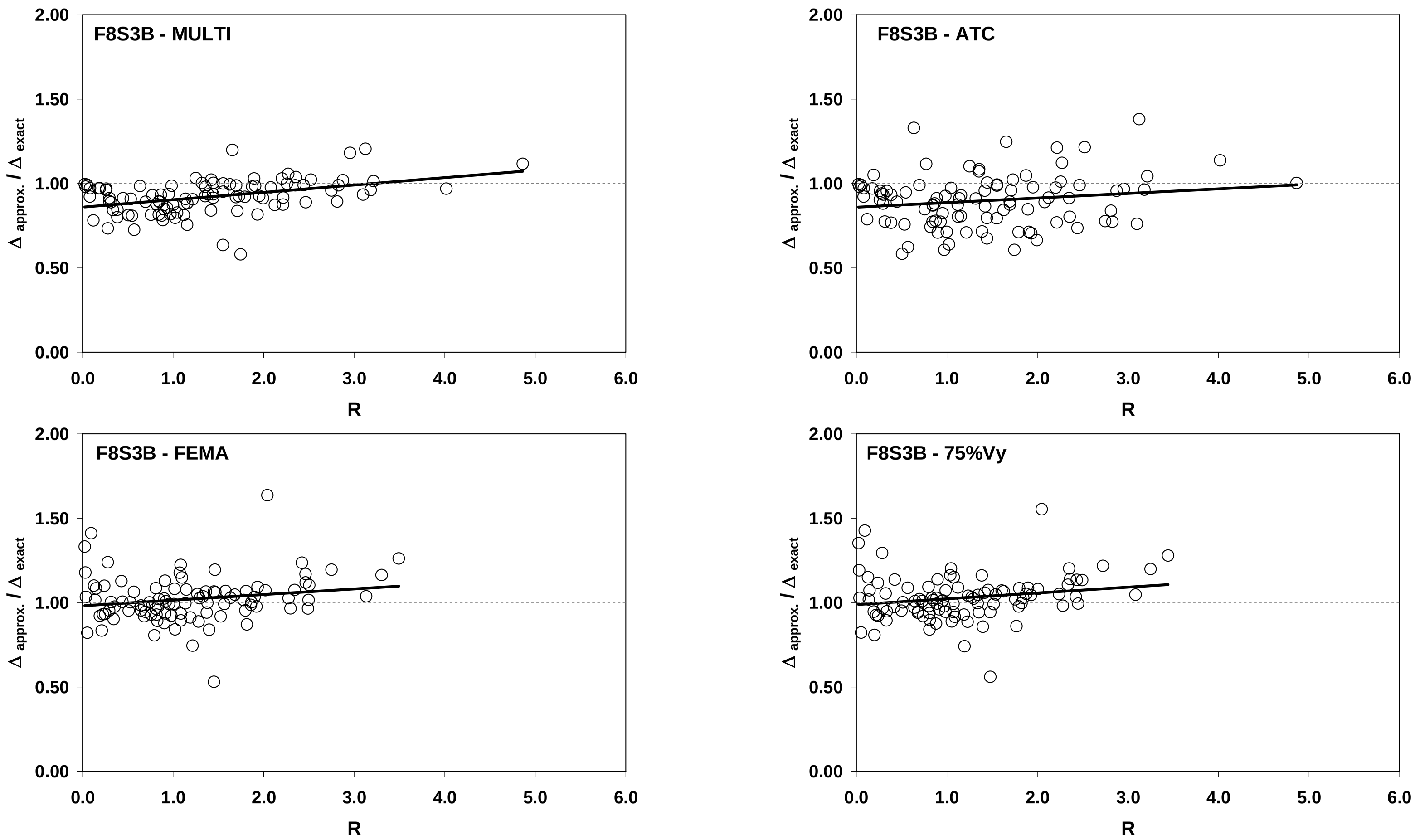


Figure A.7.14 Dependency on Strength Reduction Factor (Frame 'F8S3B' – Maximum Top Displacement)

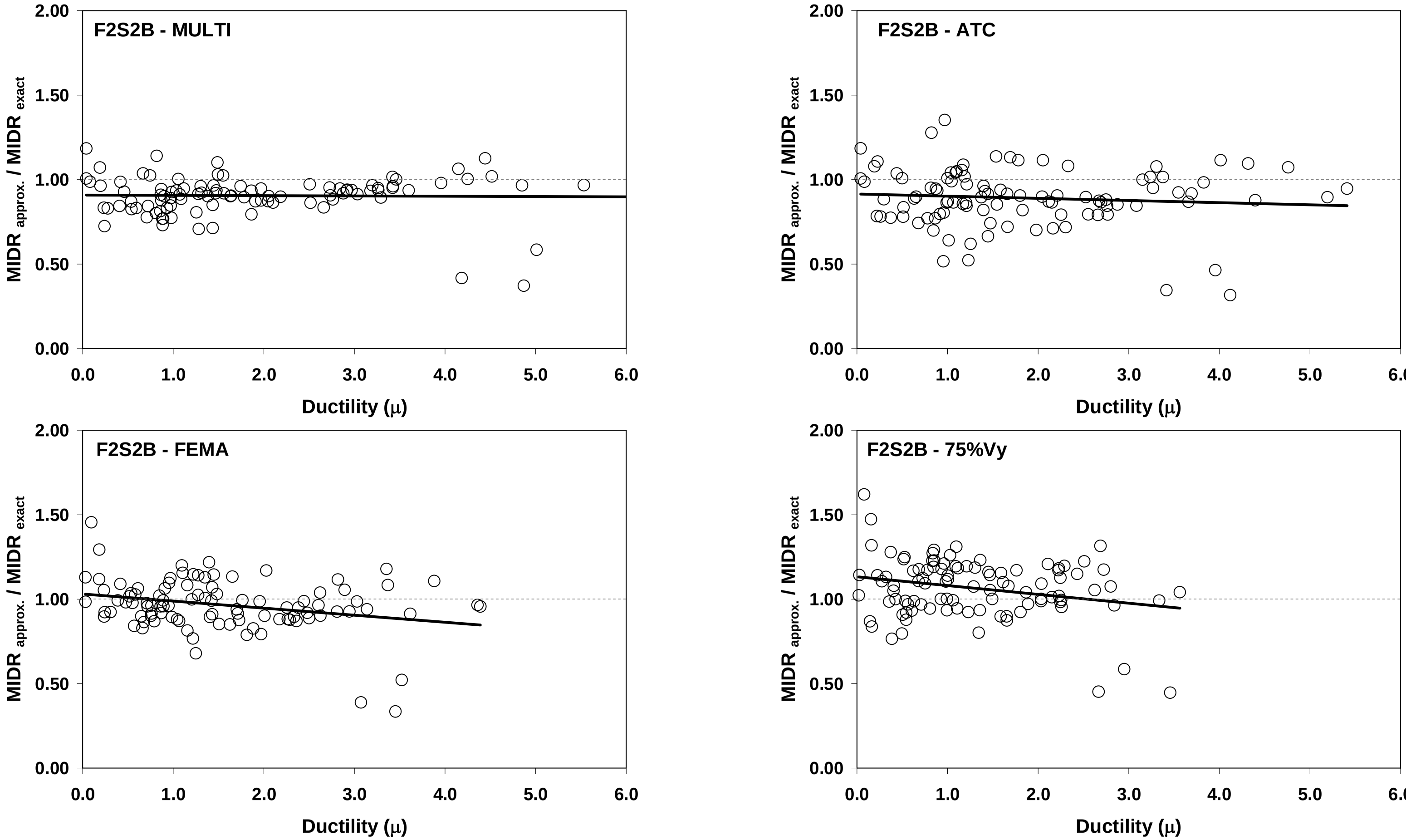


Figure A.7.15 Dependency on Ductility (Frame ‘F2S2B’ – Maximum Inter-Story Drift Ratio)

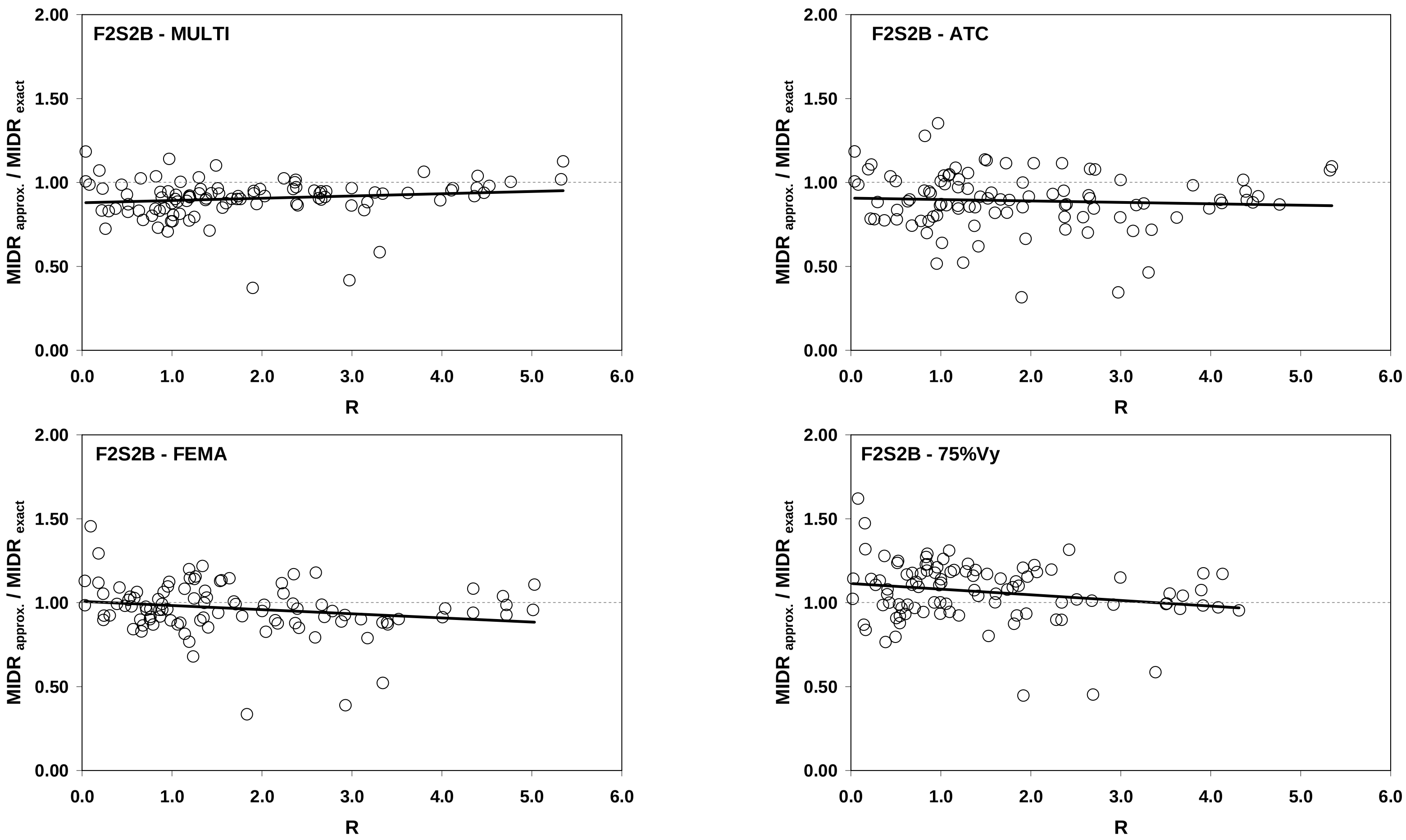


Figure A.7.16 Dependency on Strength Reduction Factor (Frame ‘F2S2B’ – Maximum Inter-Story Drift Ratio)

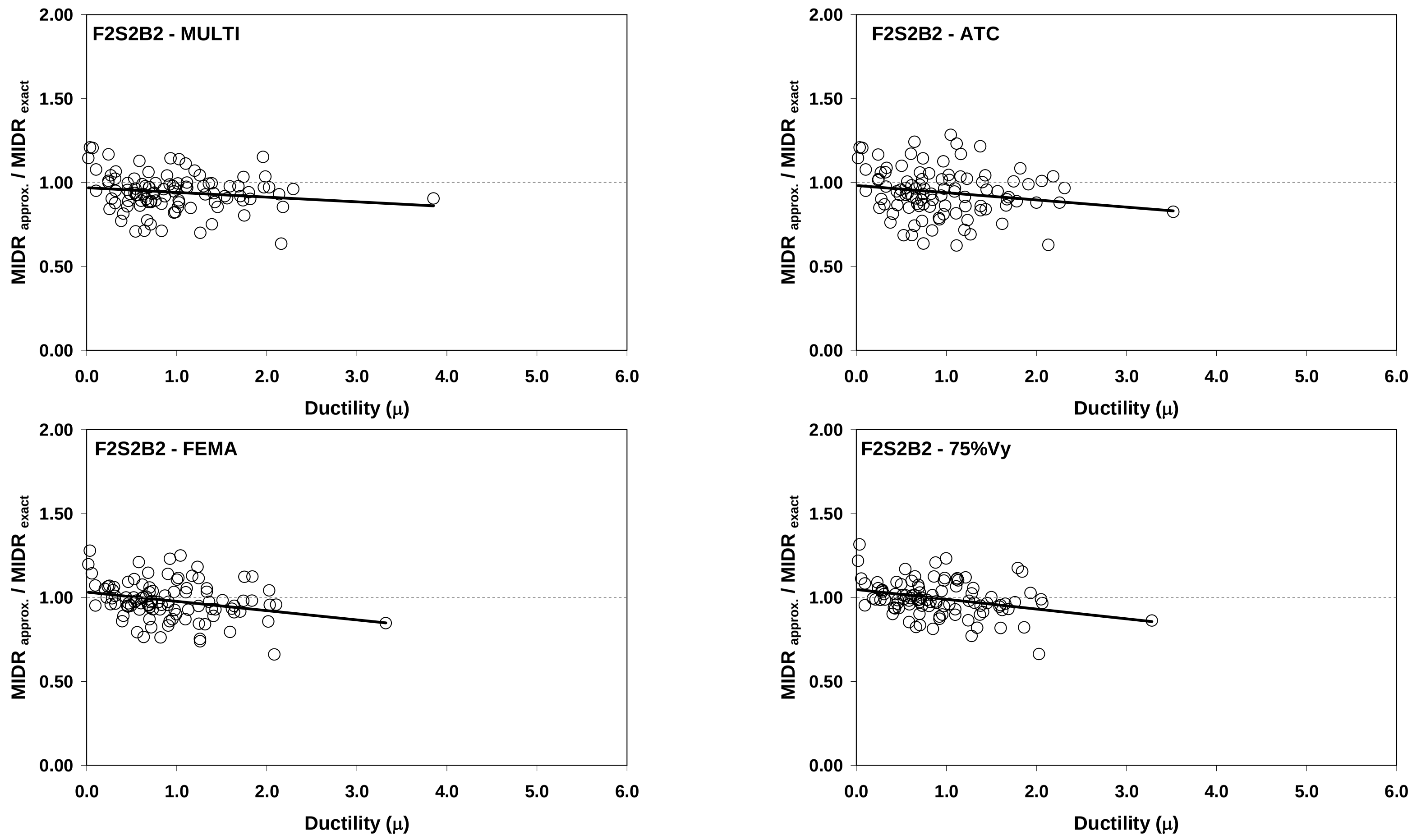


Figure A.7.17 Dependency on Ductility (Frame ‘F2S2B2’ – Maximum Inter-Story Drift Ratio)

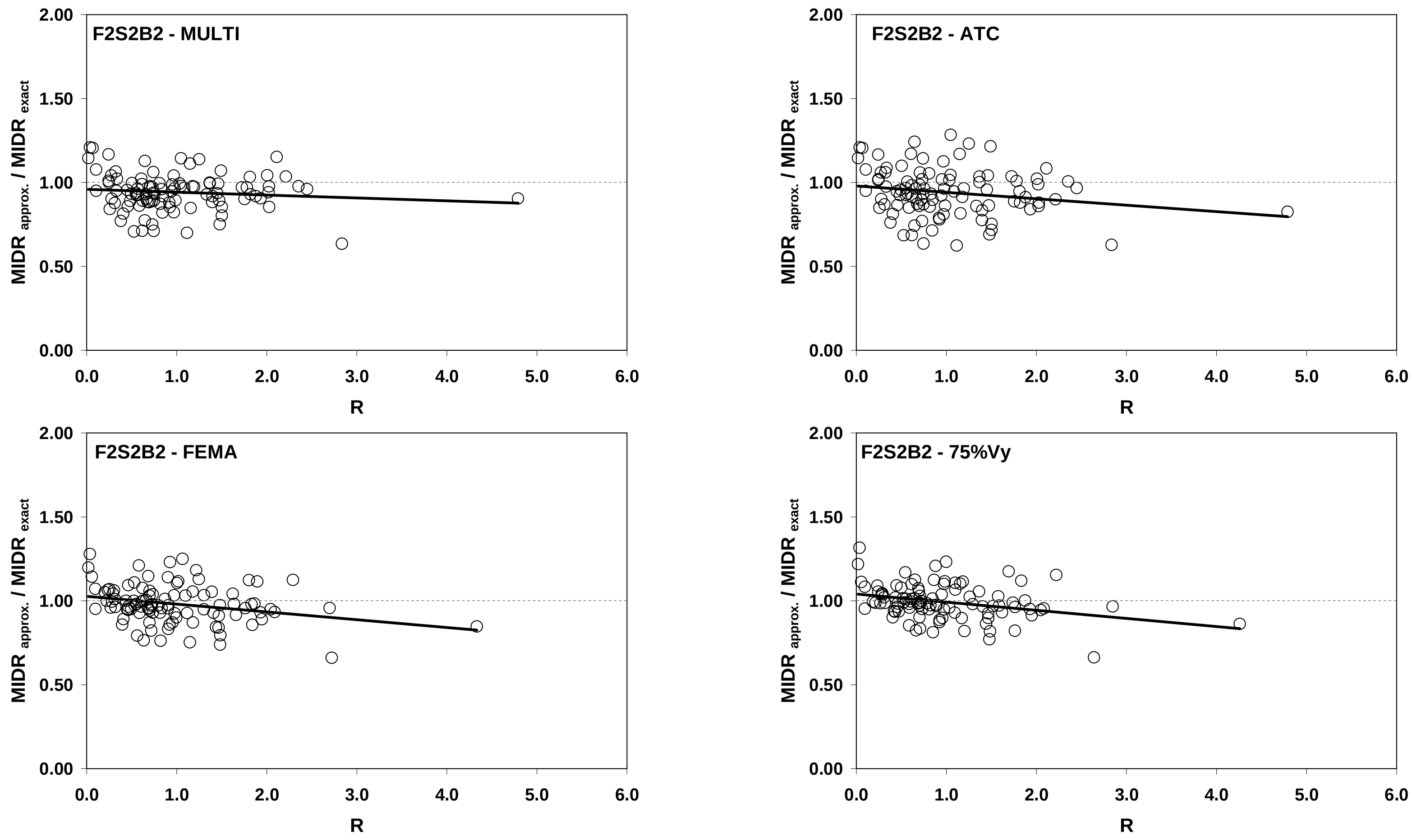


Figure A.7.18 Dependency on Strength Reduction Factor (Frame ‘F2S2B2’ – Maximum Inter-Story Drift Ratio)

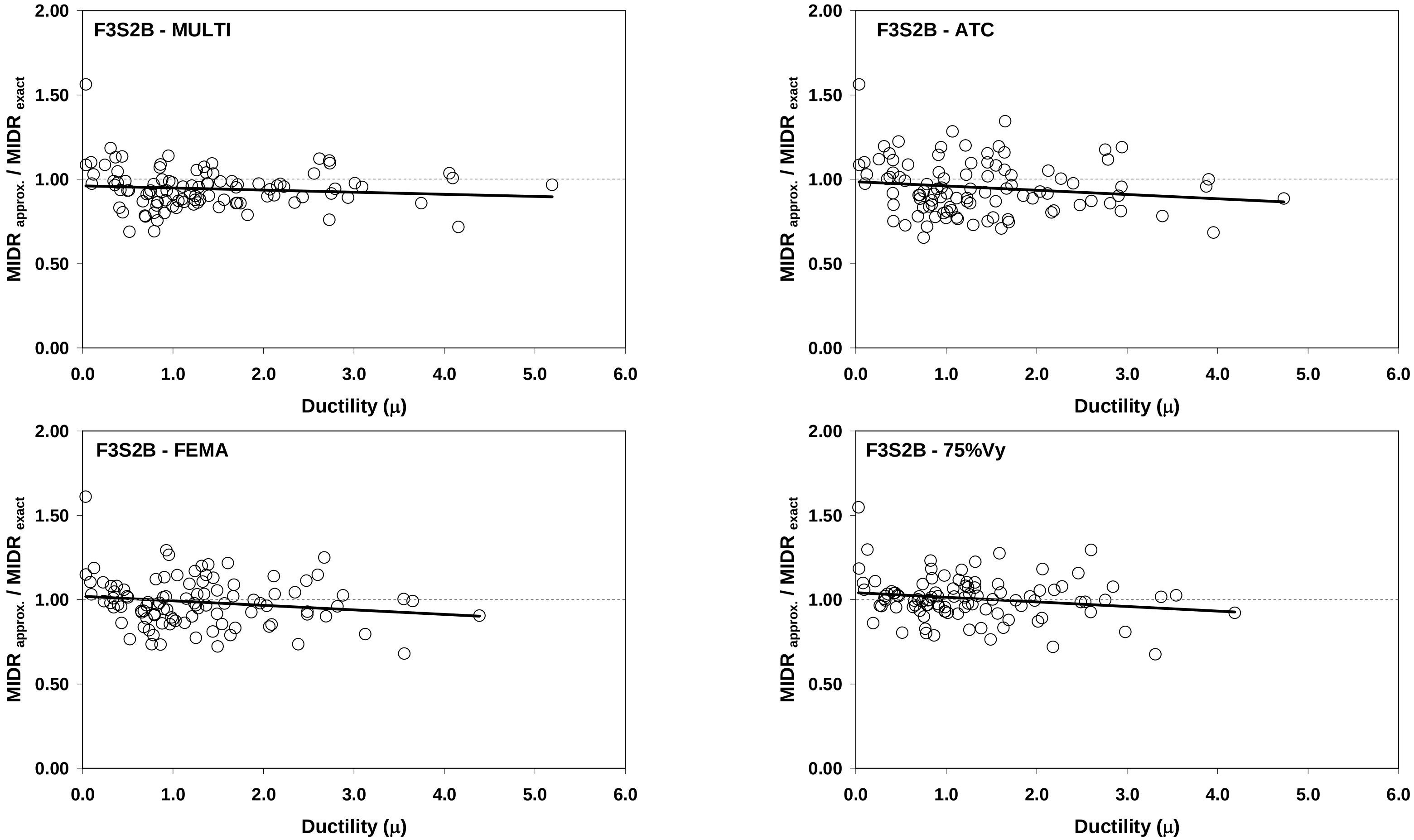


Figure A.7.19 Dependency on Ductility (Frame ‘F3S2B’ – Maximum Inter-Story Drift Ratio)

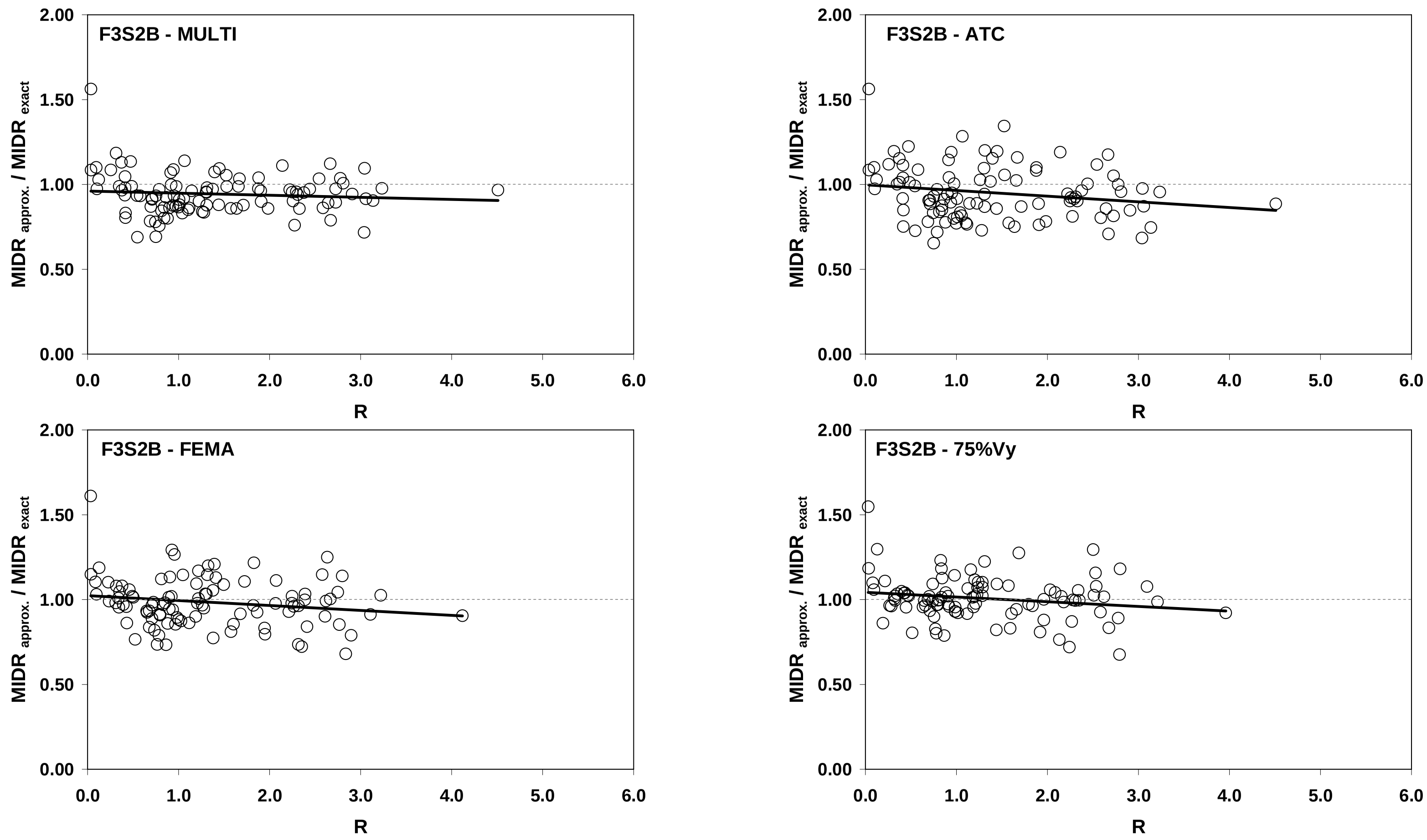


Figure A.7.20 Dependency on Strength Reduction Factor (Frame ‘F3S2B’ – Maximum Inter-Story Drift Ratio)

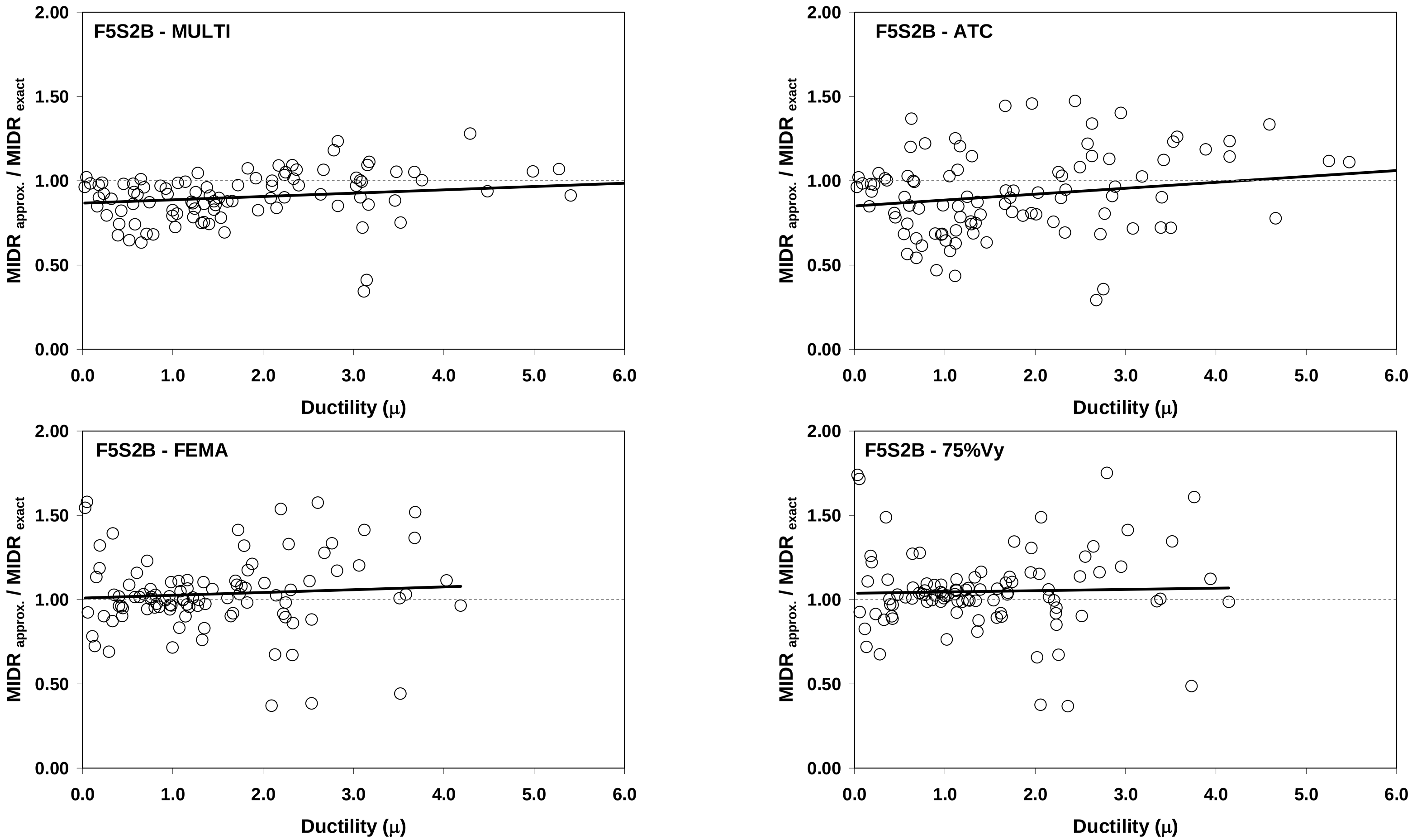


Figure A.7.21 Dependency on Ductility (Frame ‘F5S2B’ – Maximum Inter-Story Drift Ratio)

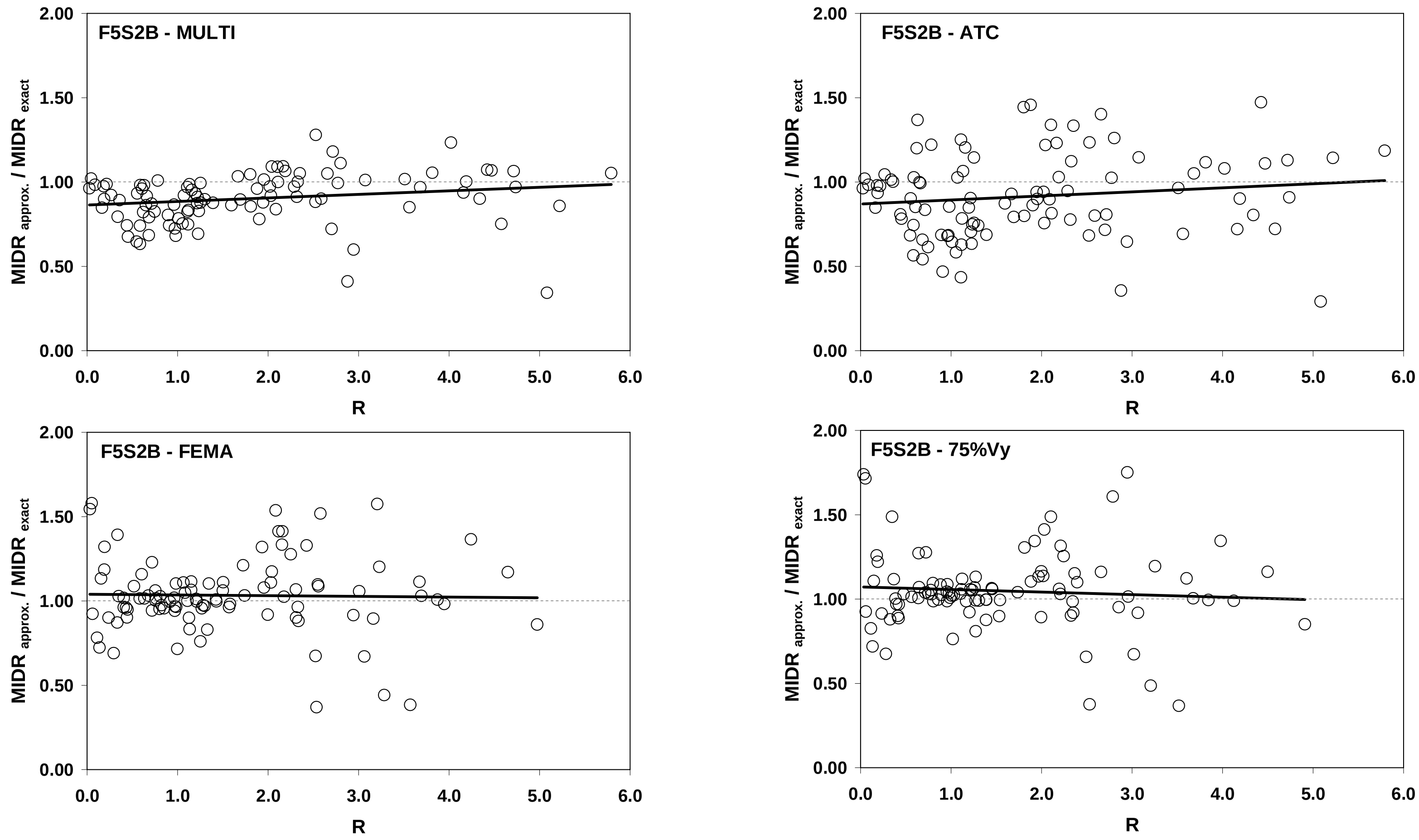


Figure A.7.22 Dependency on Strength Reduction Factor (Frame ‘F5S2B’ – Maximum Inter-Story Drift Ratio)

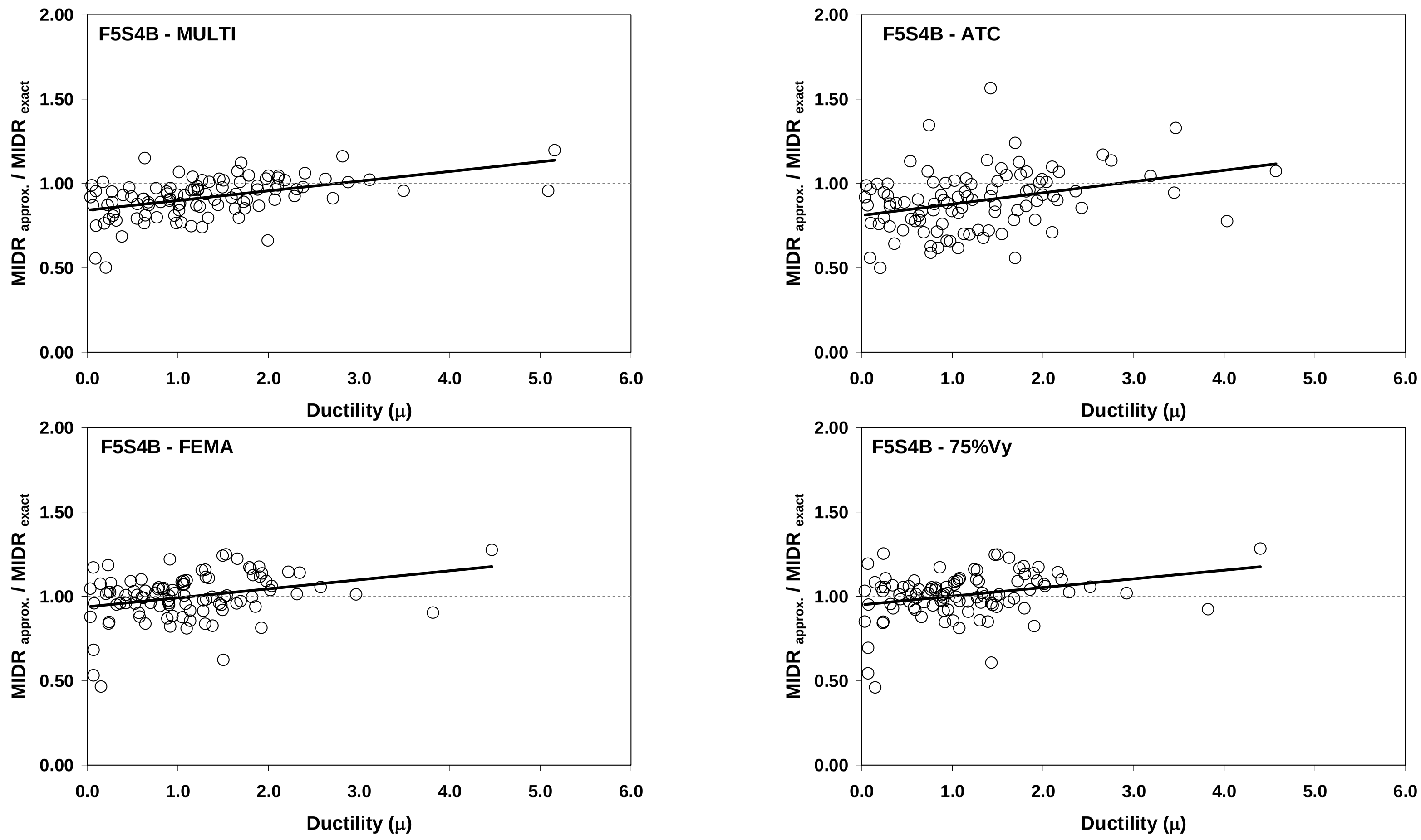


Figure A.7.23 Dependency on Ductility (Frame ‘F5S4B’ – Maximum Inter-Story Drift Ratio)

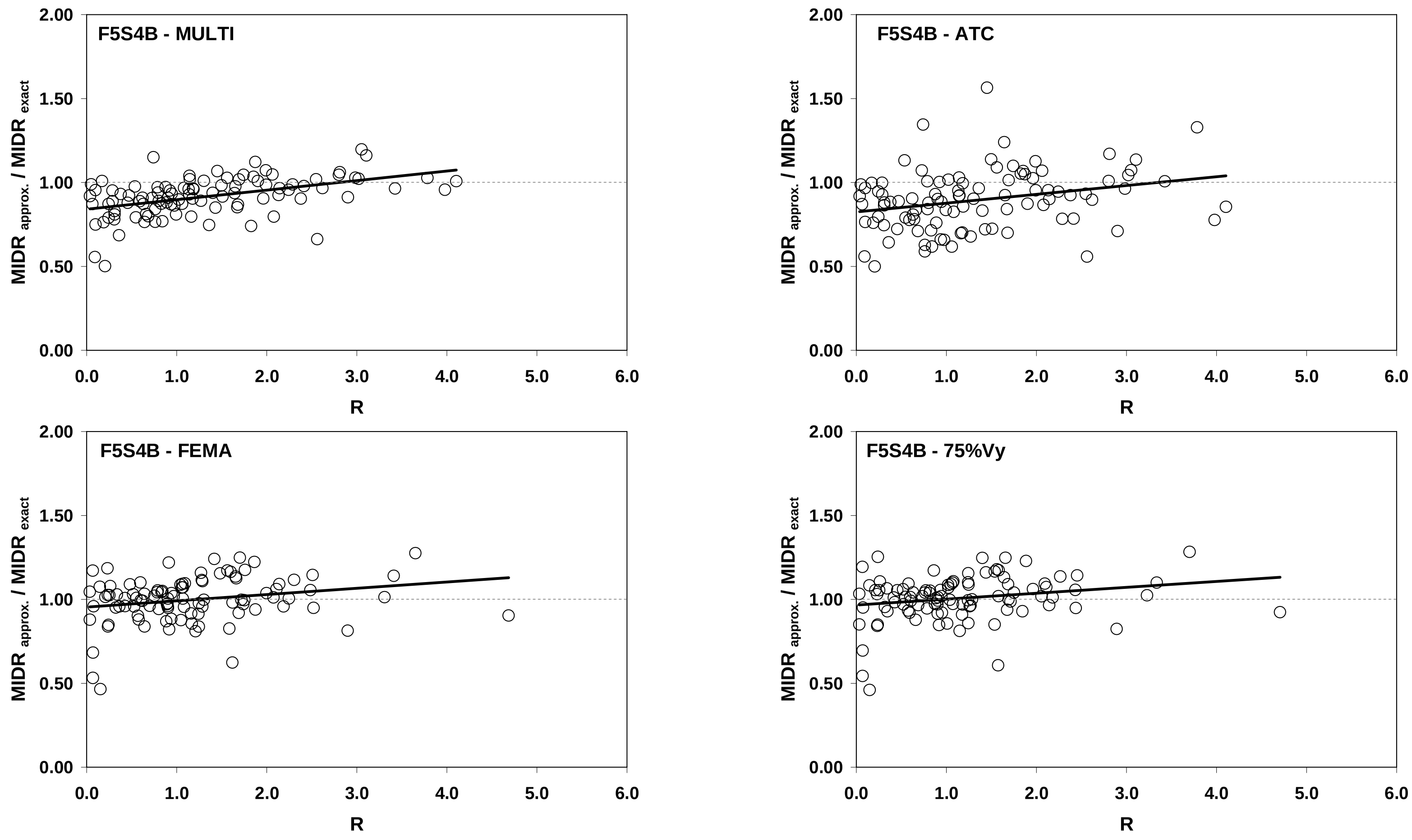


Figure A.7.24 Dependency on Strength Reduction Factor (Frame ‘F5S4B’ – Maximum Inter-Story Drift Ratio)

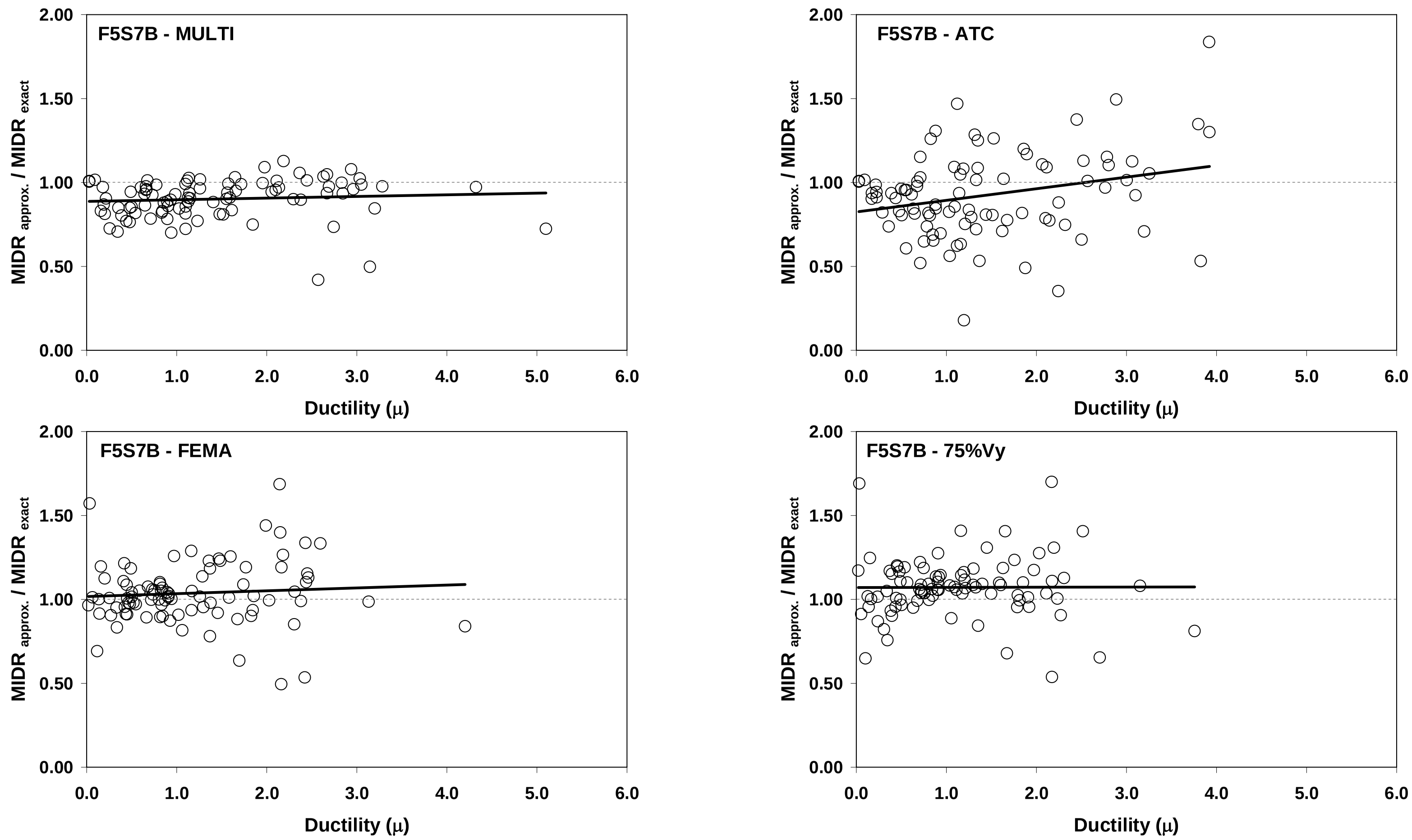


Figure A.7.25 Dependency on Ductility (Frame ‘F5S7B’ – Maximum Inter-Story Drift Ratio)

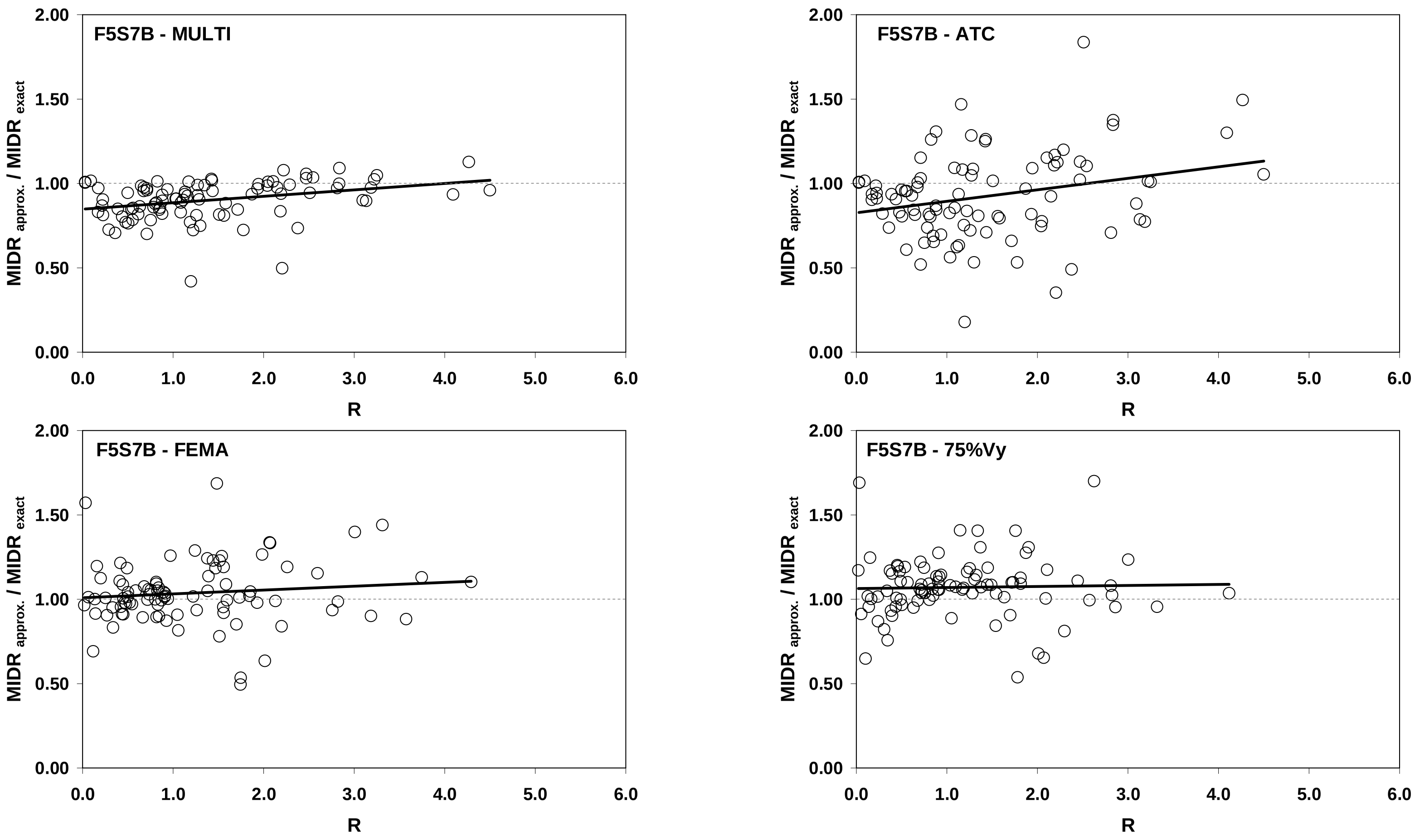


Figure A.7.26 Dependency on Strength Reduction Factor (Frame ‘F5S7B’ – Maximum Inter-Story Drift Ratio)

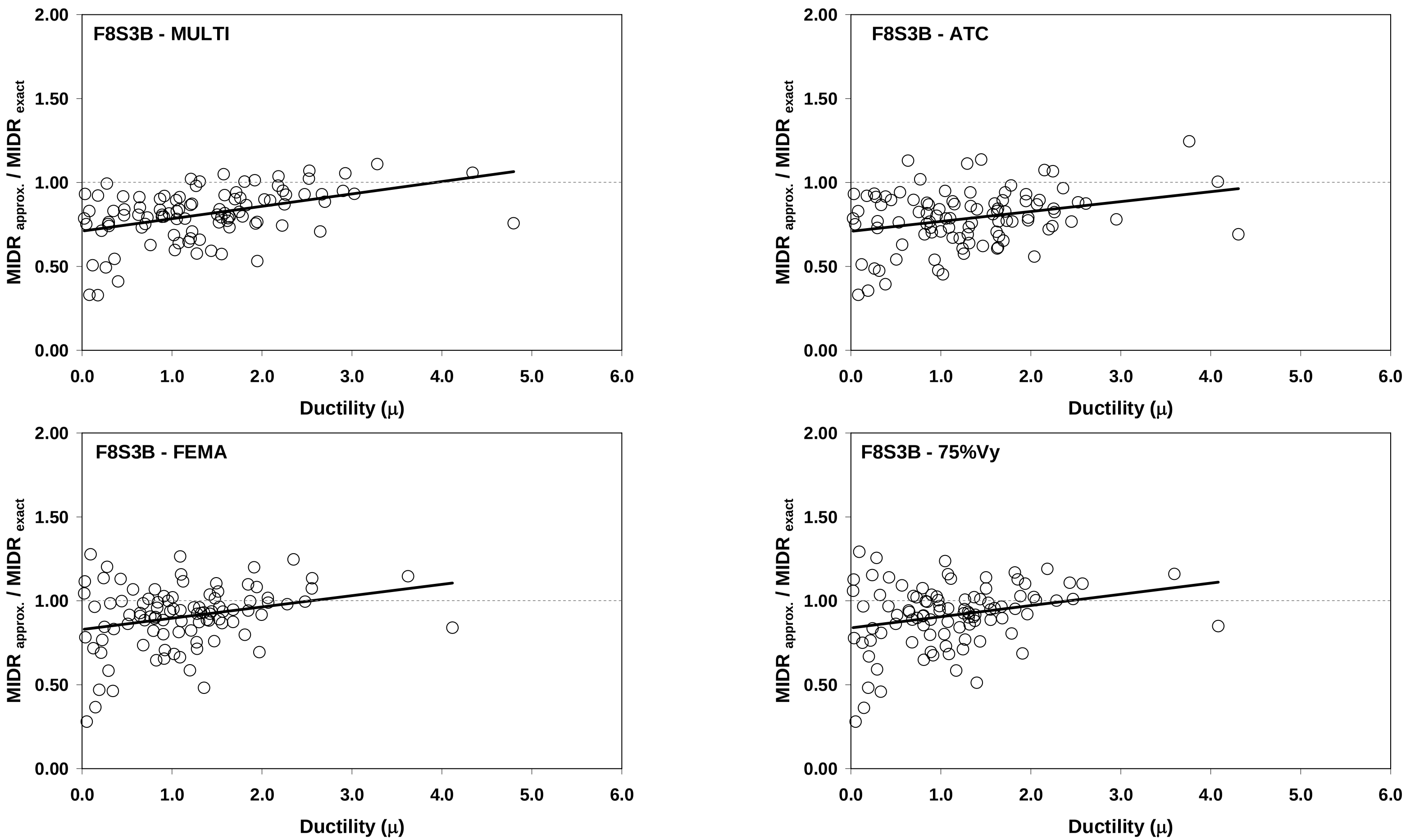


Figure A.7.27 Dependency on Ductility (Frame ‘F8S3B’ – Maximum Inter-Story Drift Ratio)

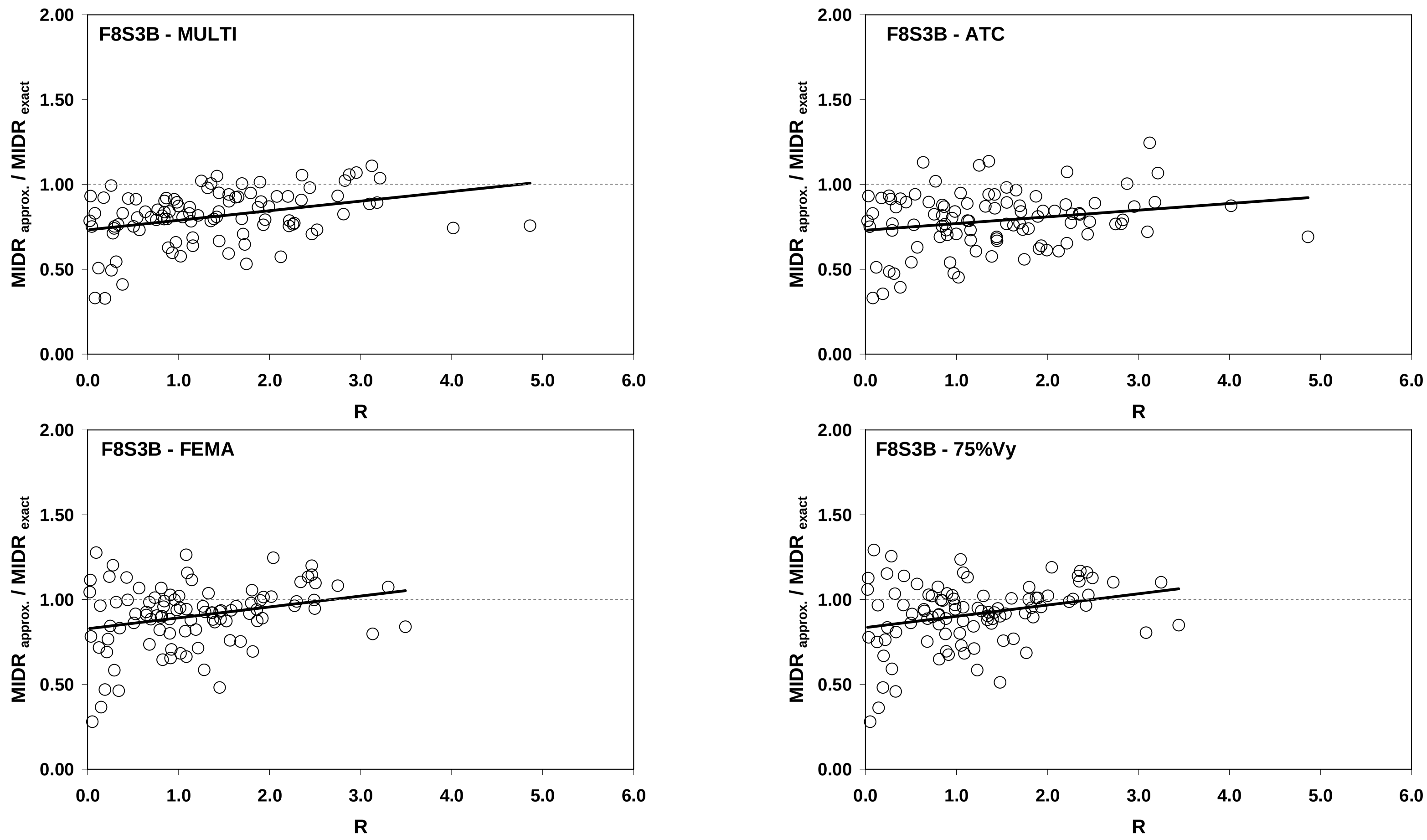


Figure A.7.28 Dependency on Strength Reduction Factor (Frame 'F8S3B' – Maximum Inter-Story Drift Ratio)

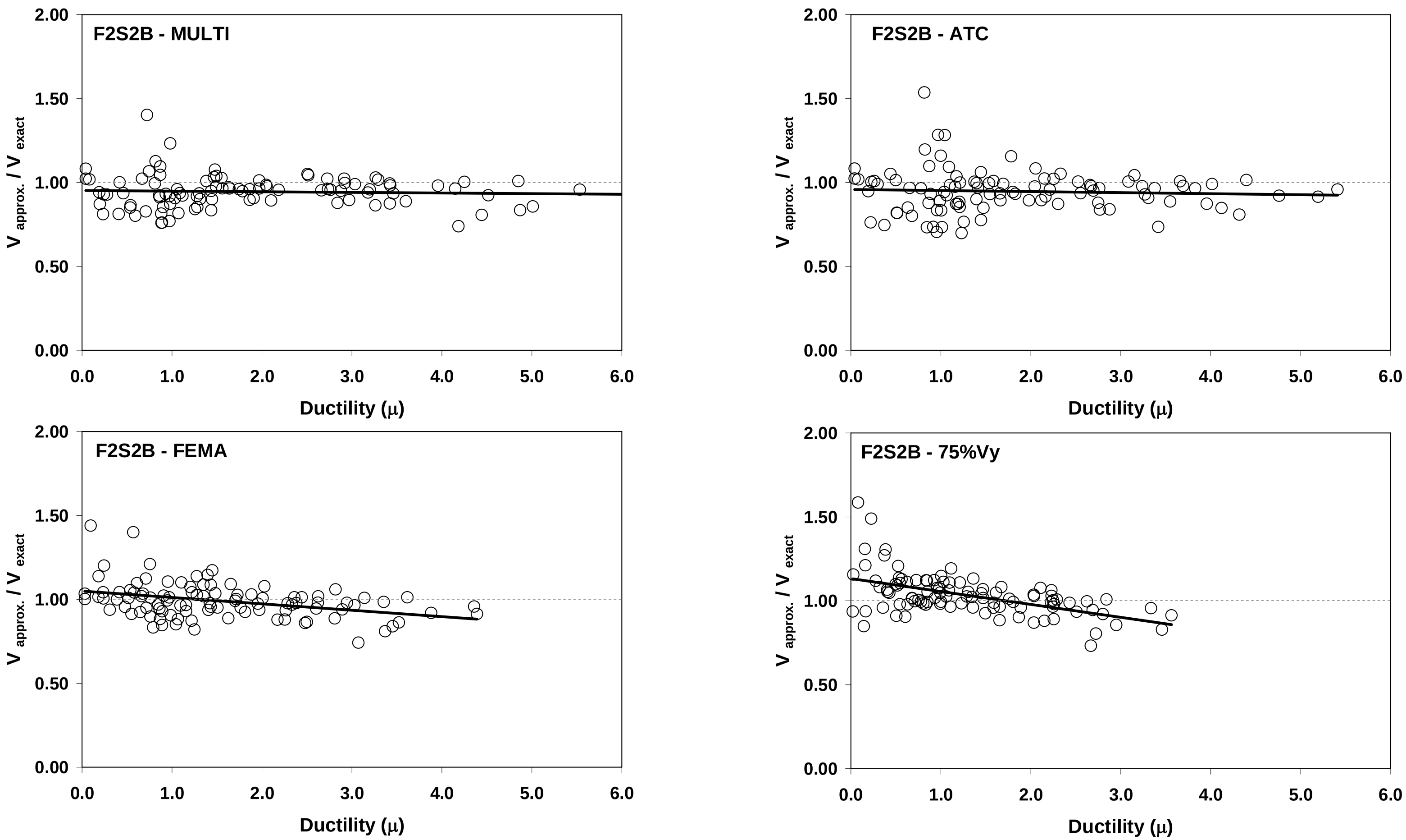


Figure A.7.29 Dependency on Ductility (Frame ‘F2S2B’ – Maximum Base Shear)

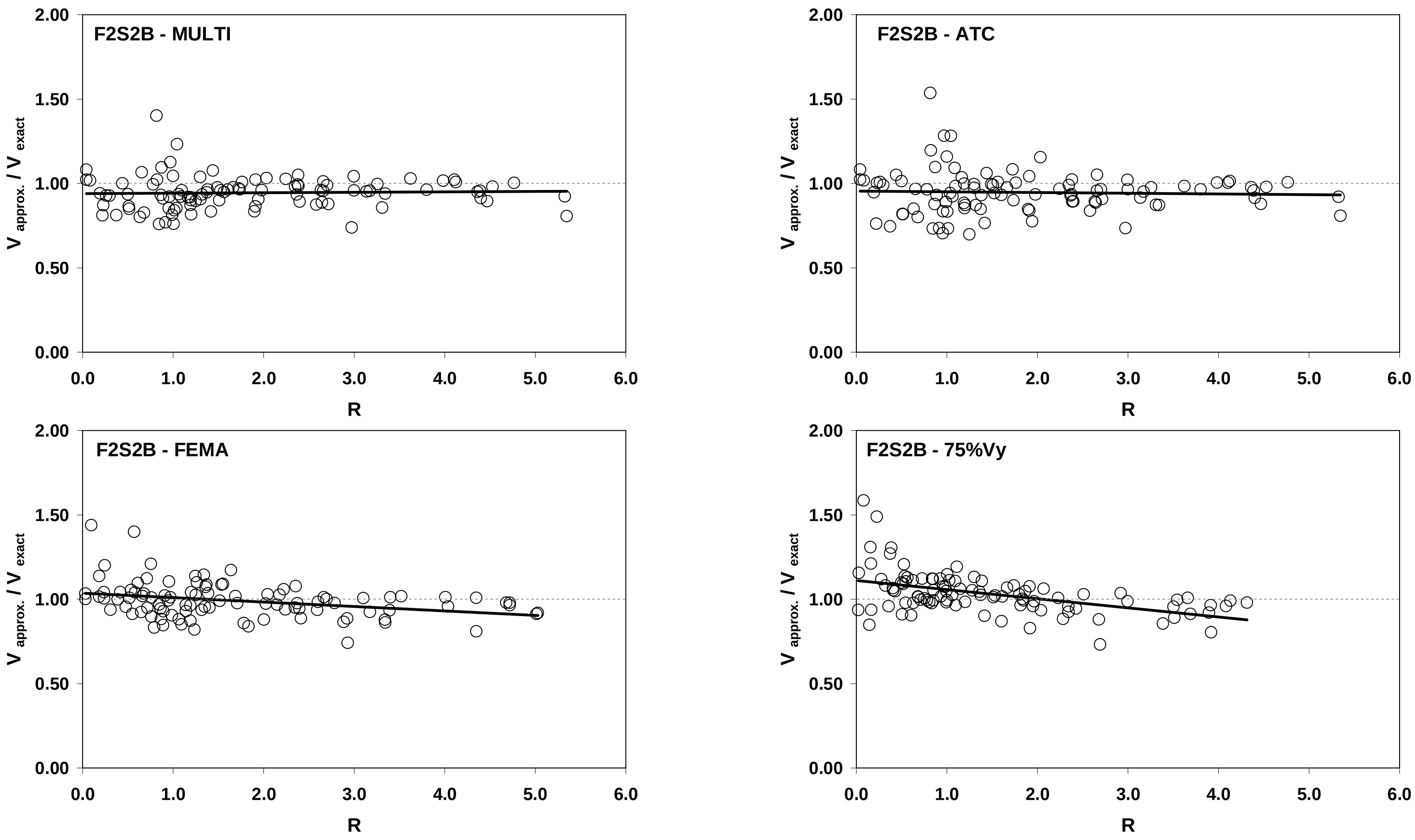


Figure A.7.30 Dependency on Strength Reduction Factor (Frame ‘F2S2B’ – Maximum Base Shear)

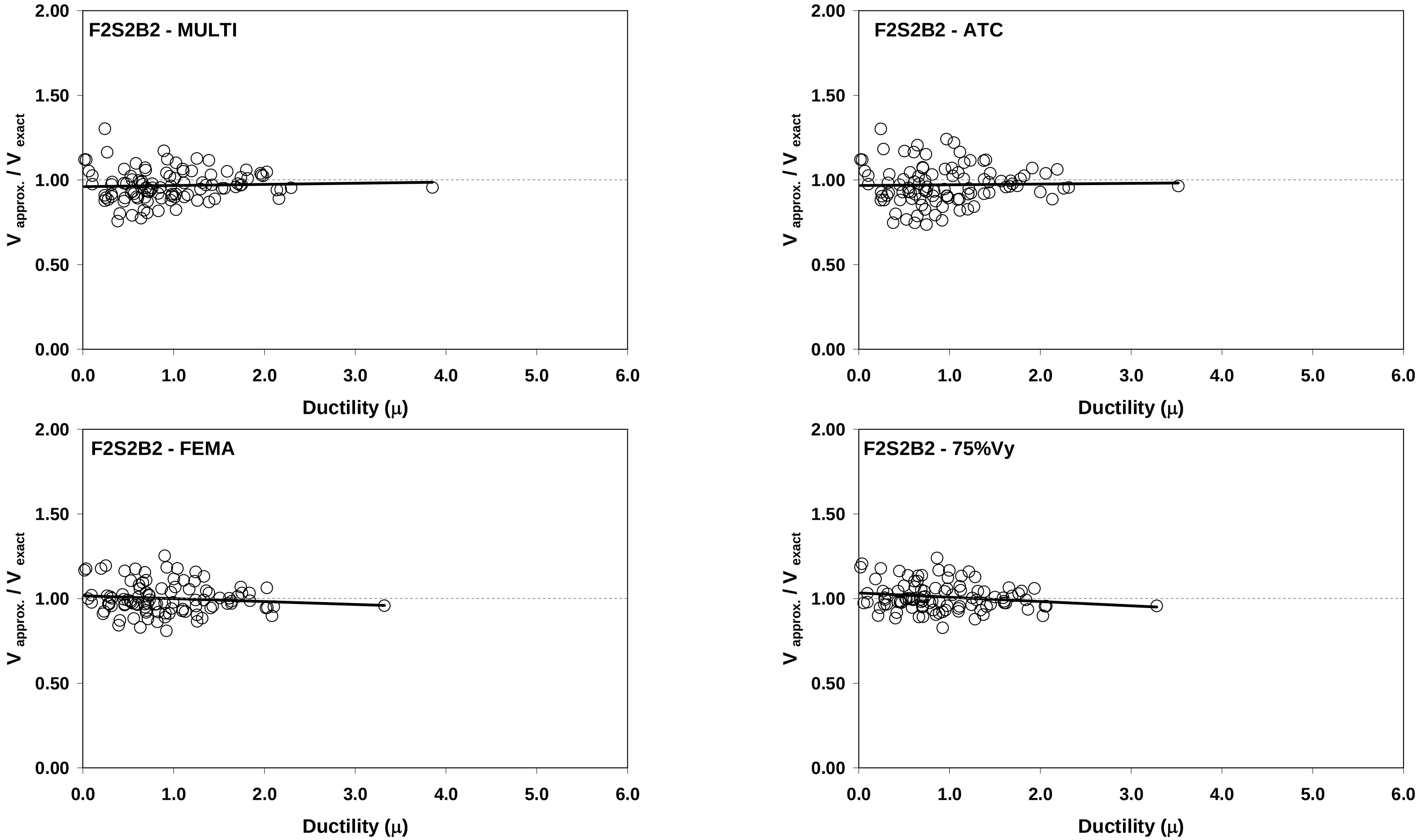


Figure A.7.31 Dependency on Ductility (Frame ‘F2S2B2’ – Maximum Base Shear)

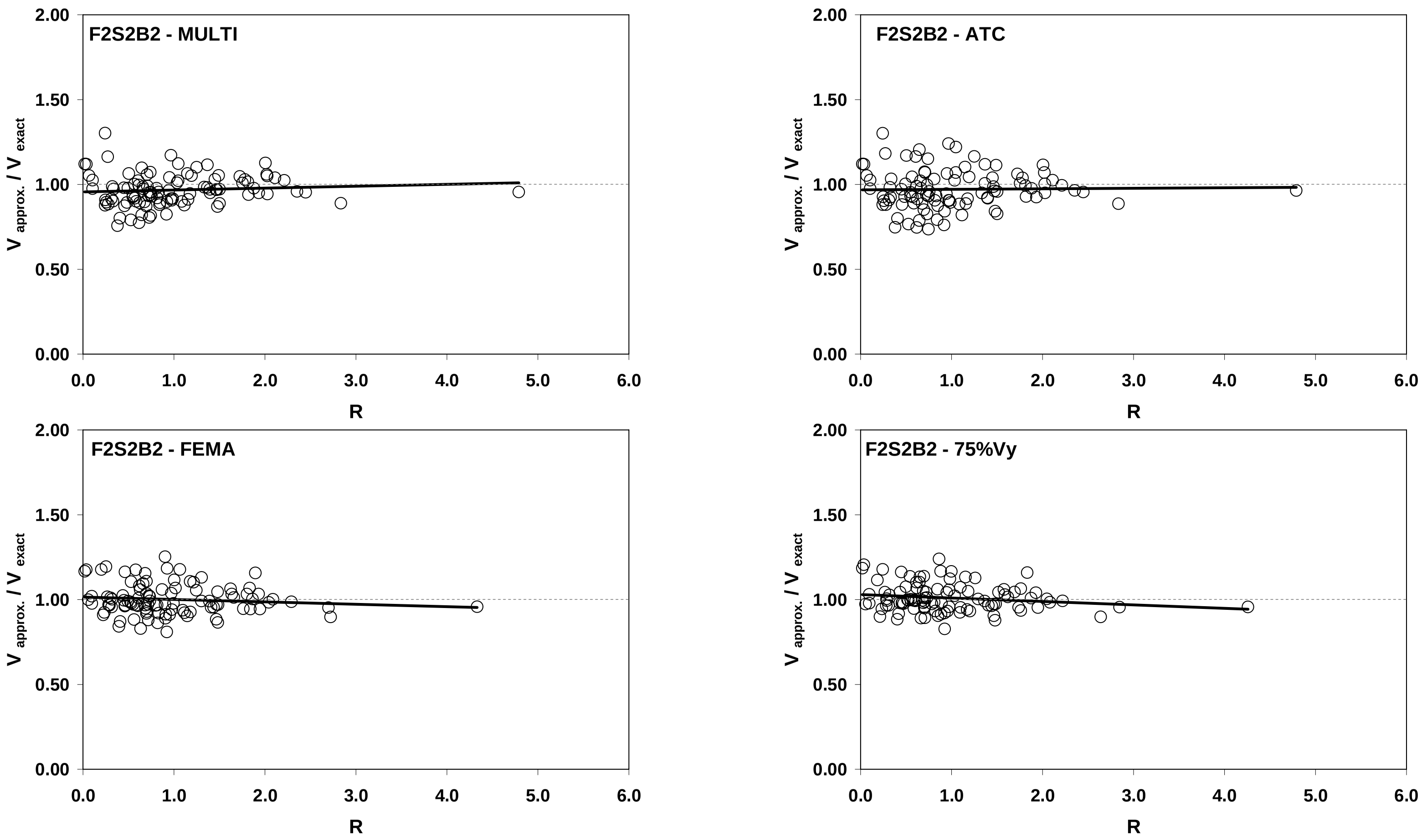


Figure A.7.32 Dependency on Strength Reduction Factor (Frame ‘F2S2B2’ – Maximum Base Shear)

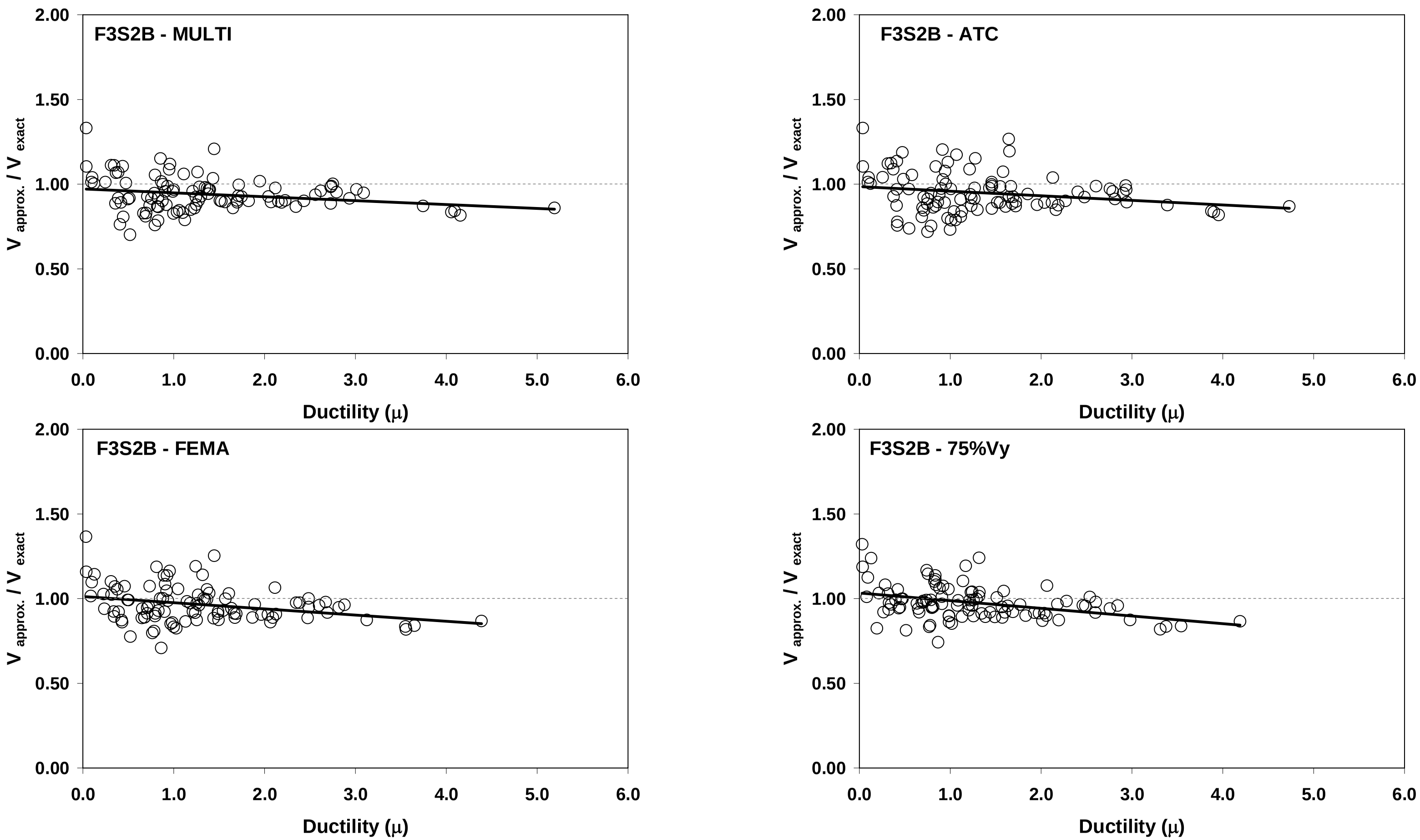


Figure A.7.33 Dependency on Ductility (Frame ‘F3S2B’ – Maximum Base Shear)

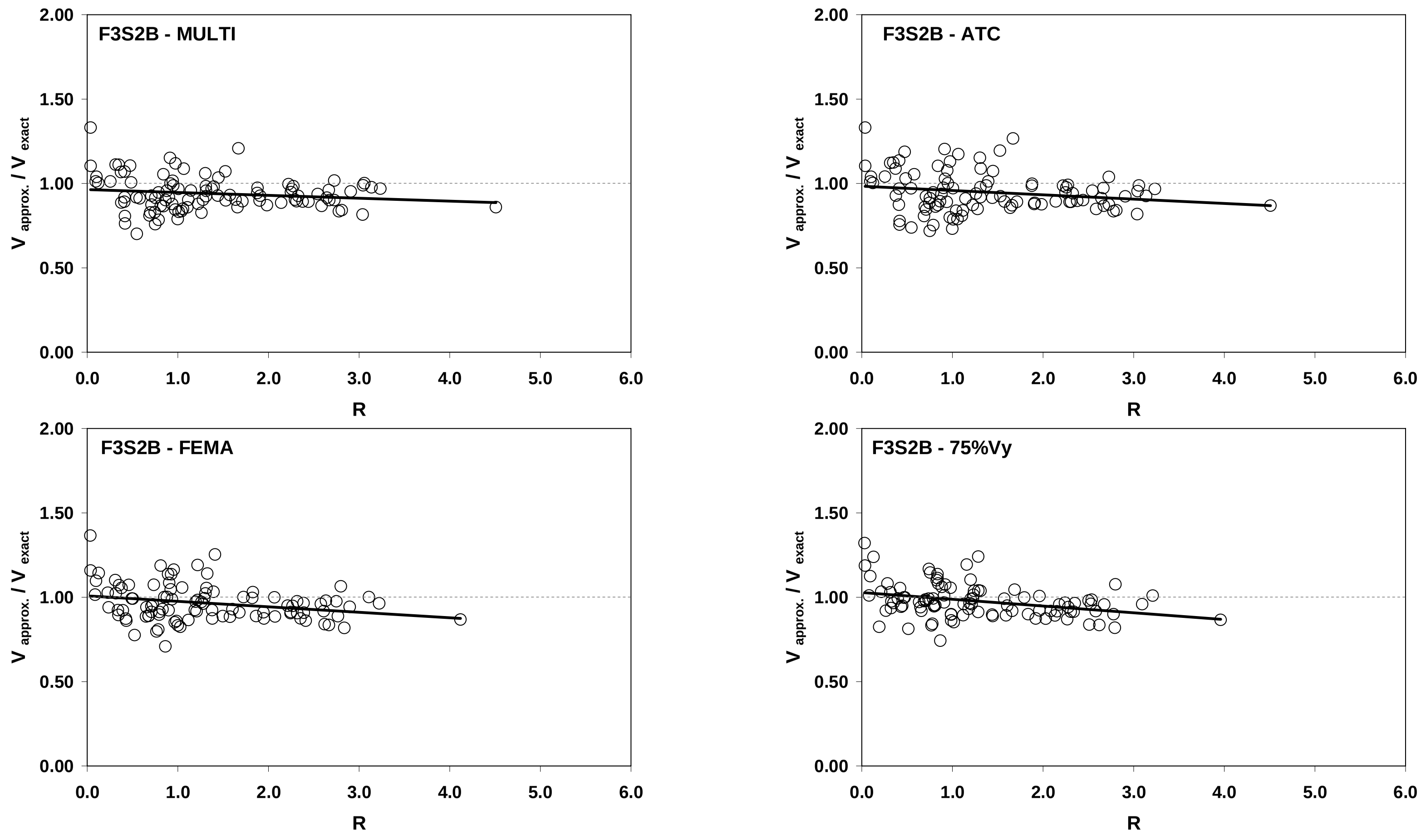


Figure A.7.34 Dependency on Strength Reduction Factor (Frame ‘F3S2B’ – Maximum Base Shear)

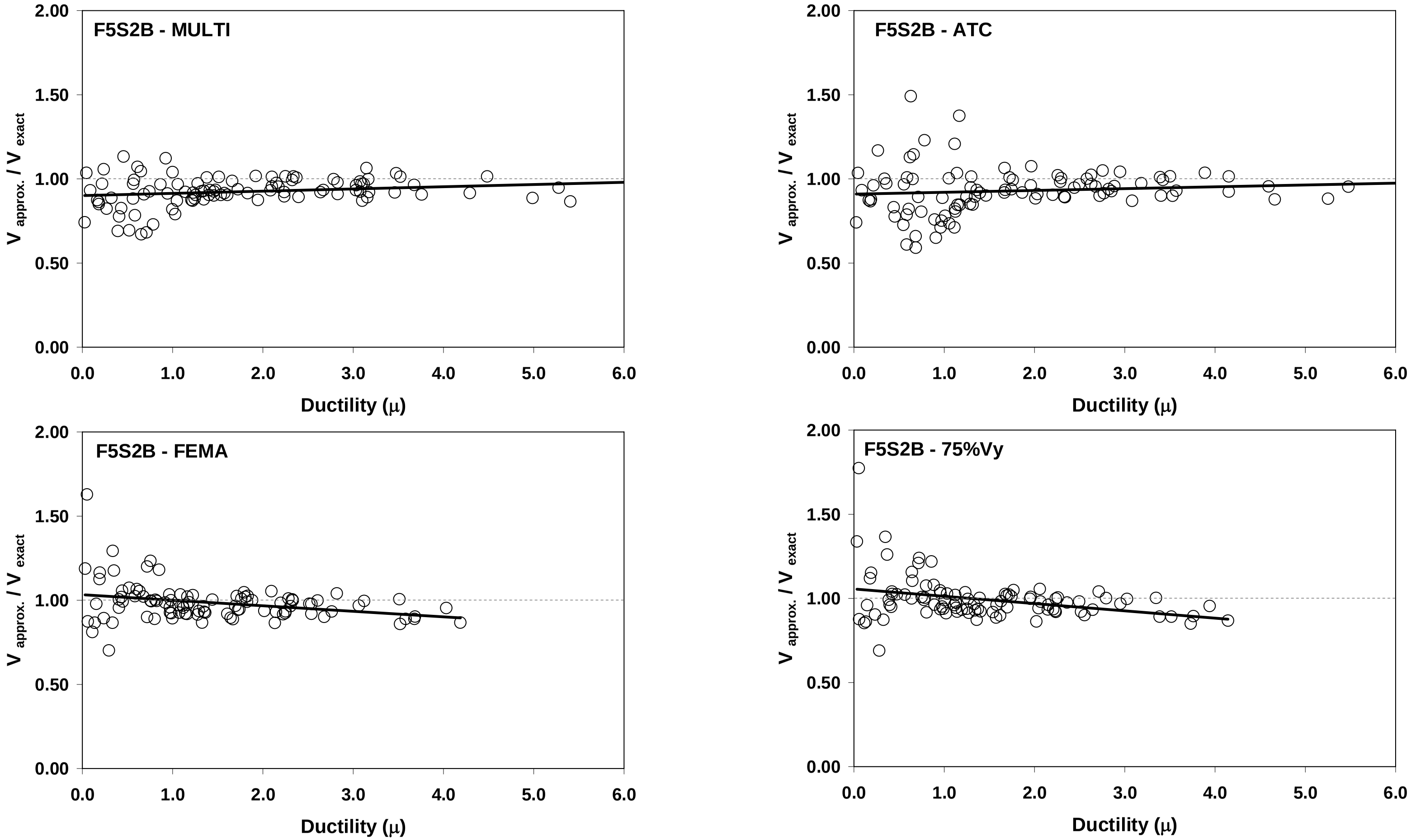


Figure A.7.35 Dependency on Ductility (Frame ‘F5S2B’ – Maximum Base Shear)

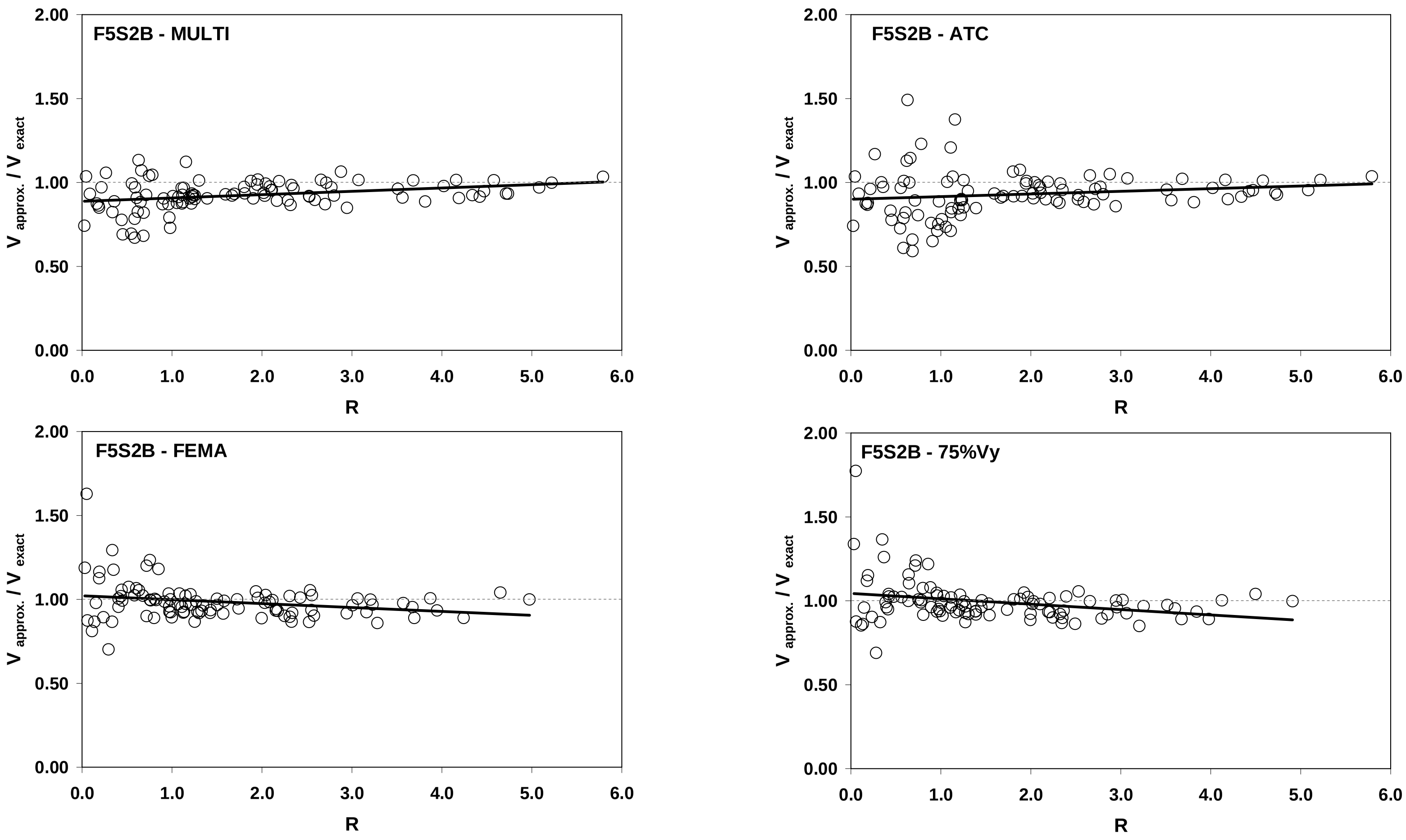


Figure A.7.36 Dependency on Strength Reduction Factor (Frame ‘F5S2B’ – Maximum Base Shear)

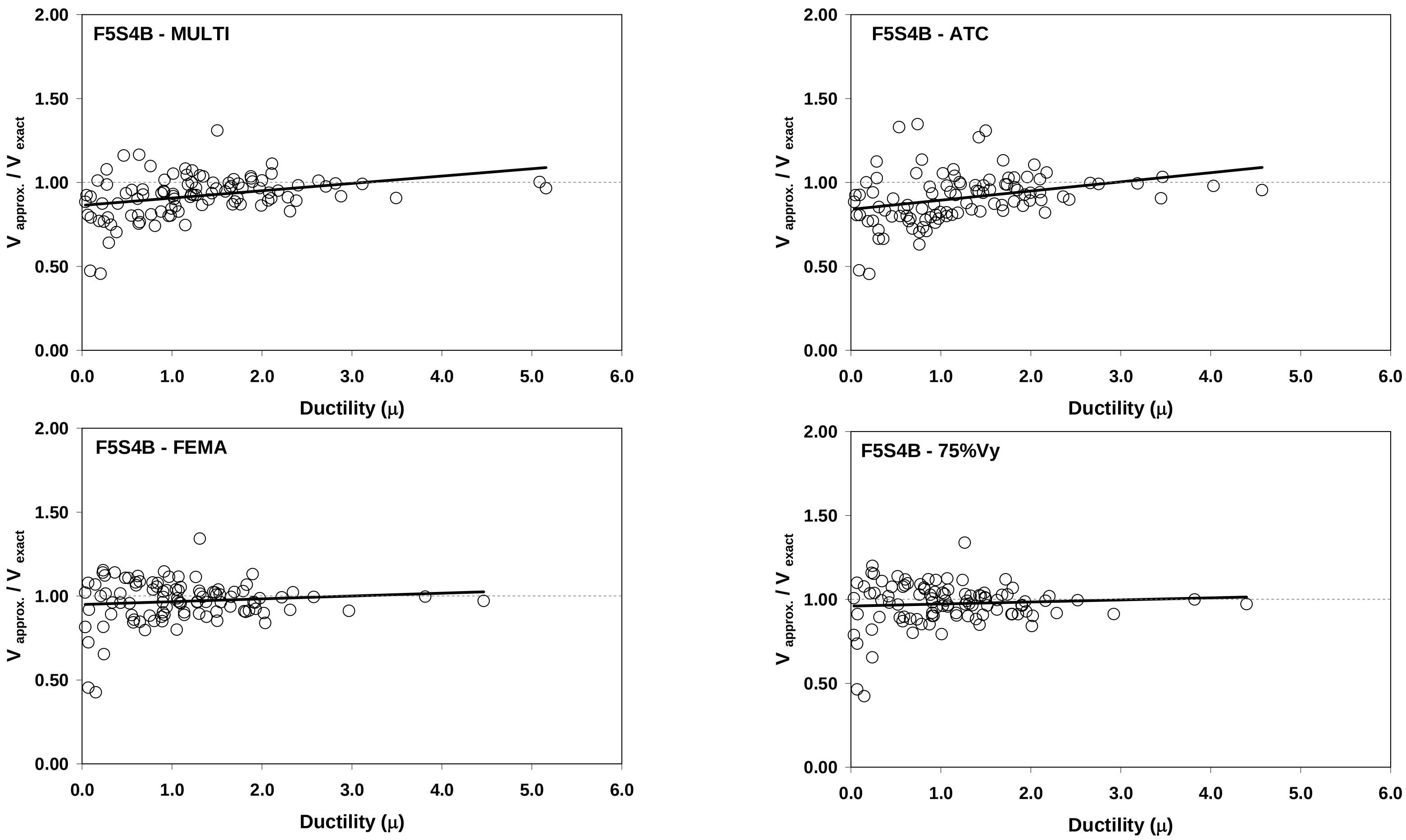


Figure A.7.37 Dependency on Ductility (Frame ‘F5S4B’ – Maximum Base Shear)

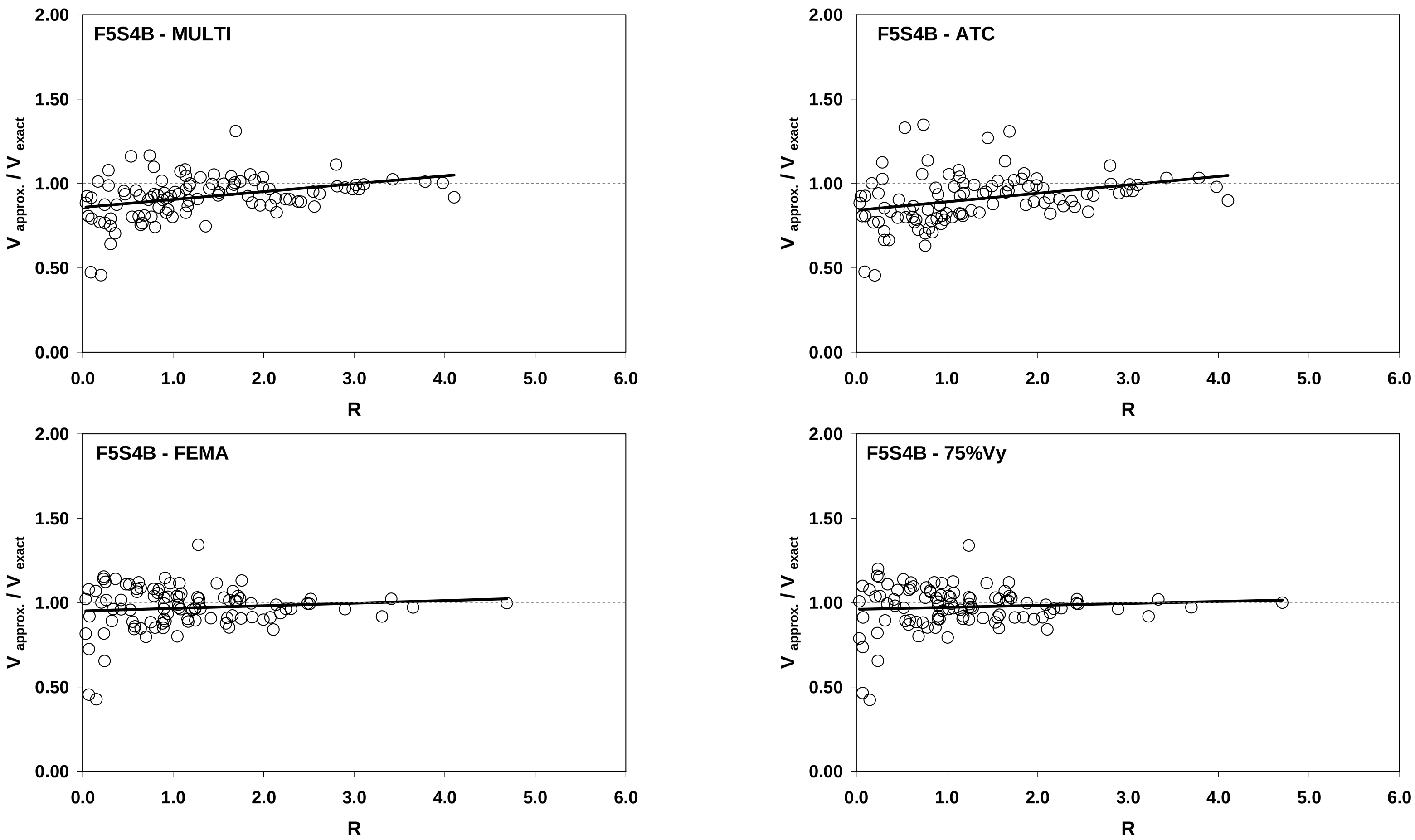


Figure A.7.38 Dependency on Strength Reduction Factor (Frame ‘F5S4B’ – Maximum Base Shear)

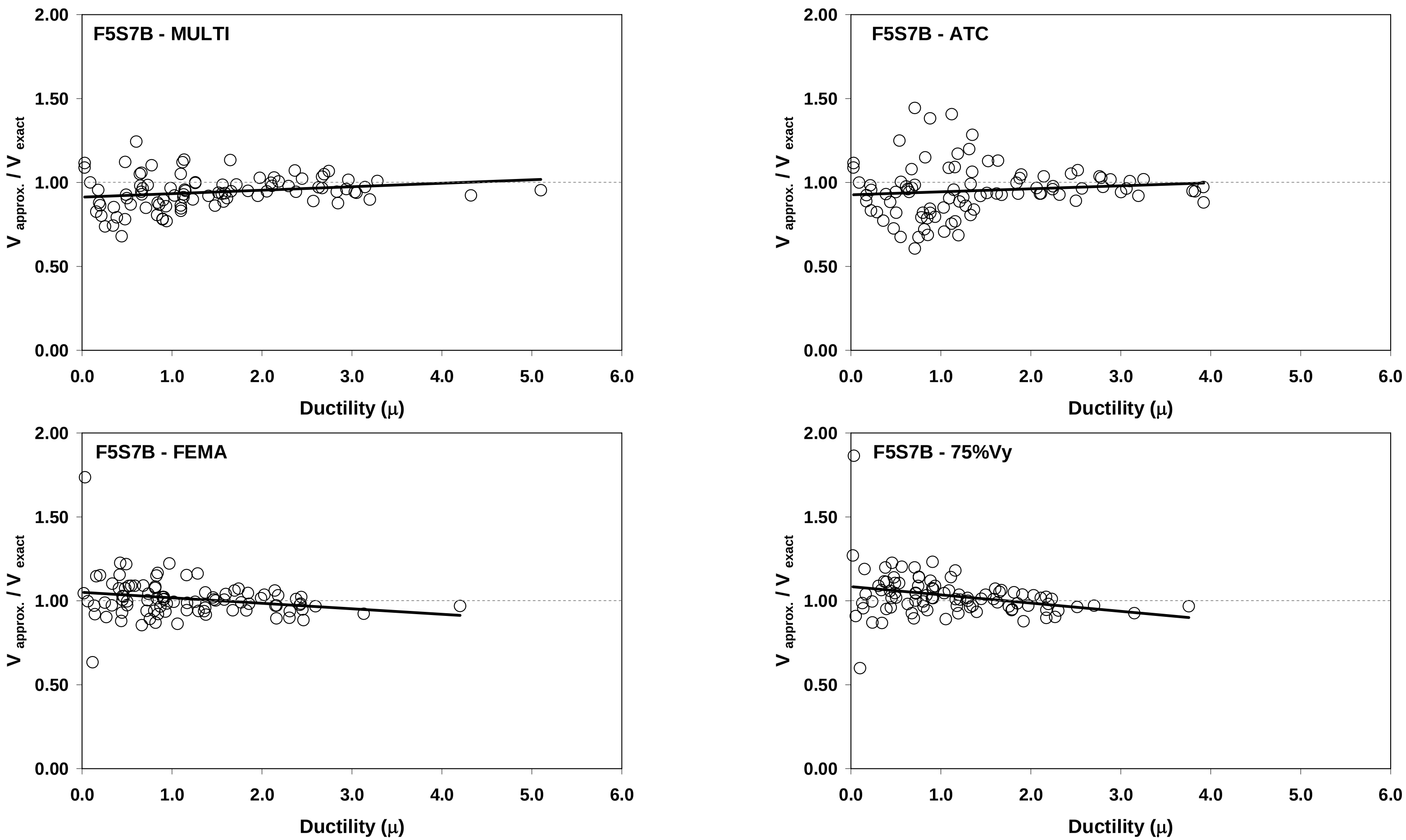


Figure A.7.39 Dependency on Ductility (Frame ‘F5S7B’ – Maximum Base Shear)

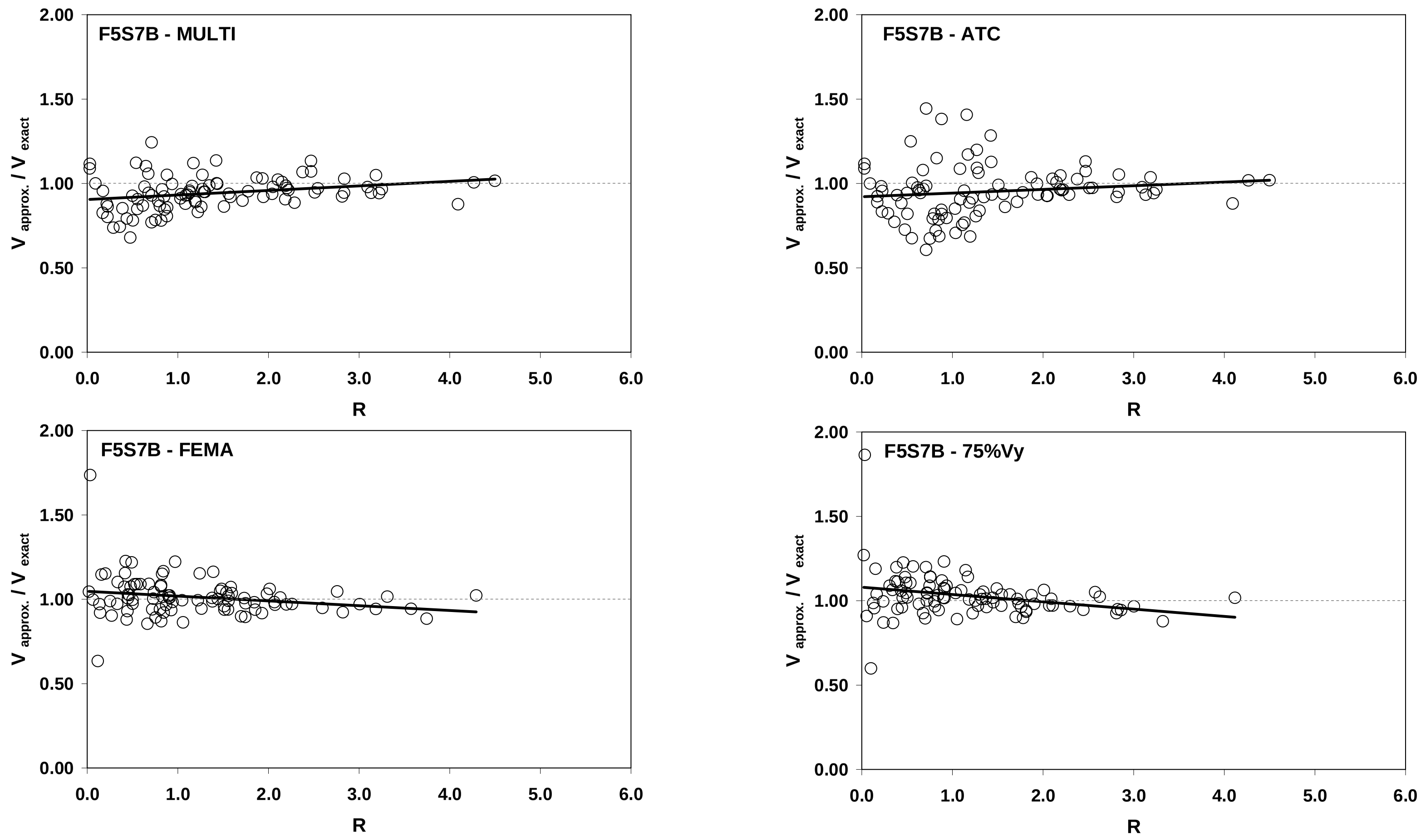


Figure A.7.40 Dependency on Strength Reduction Factor (Frame ‘F5S7B’ – Maximum Base Shear)

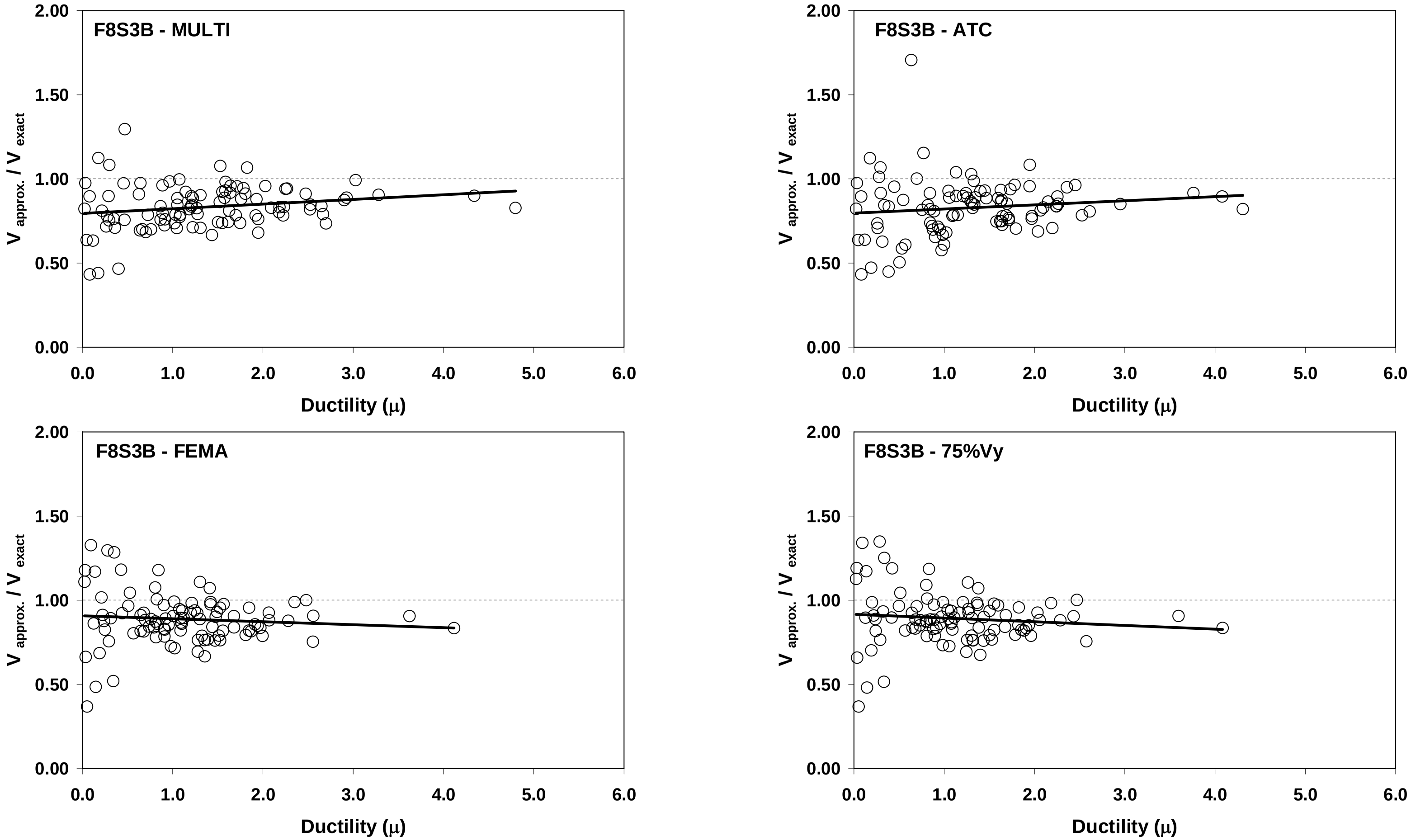


Figure A.7.41 Dependency on Ductility (Frame 'F8S3B' – Maximum Base Shear)

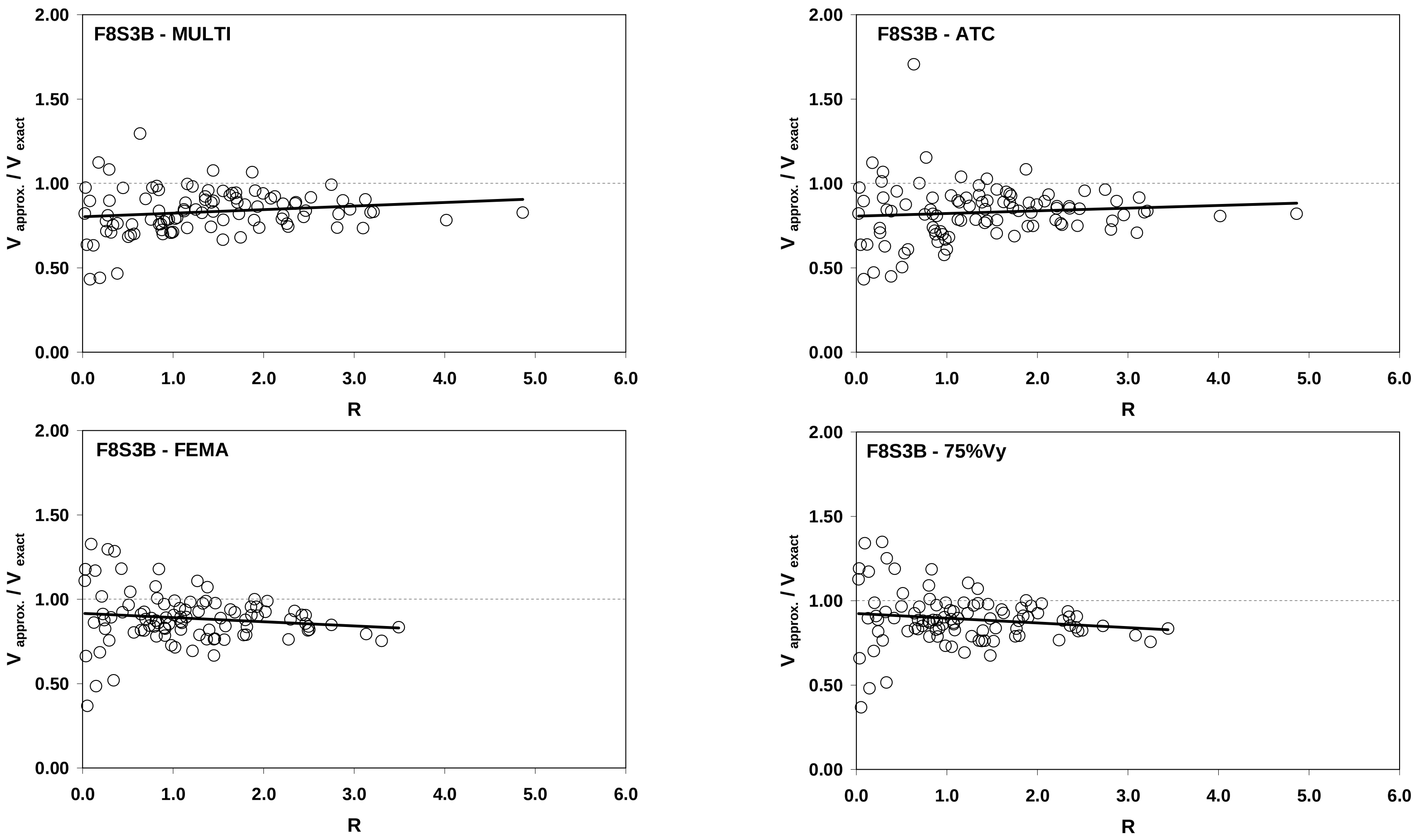


Figure A.7.42 Dependency on Strength Reduction Factor (Frame ‘F8S3B’ – Maximum Base Shear)

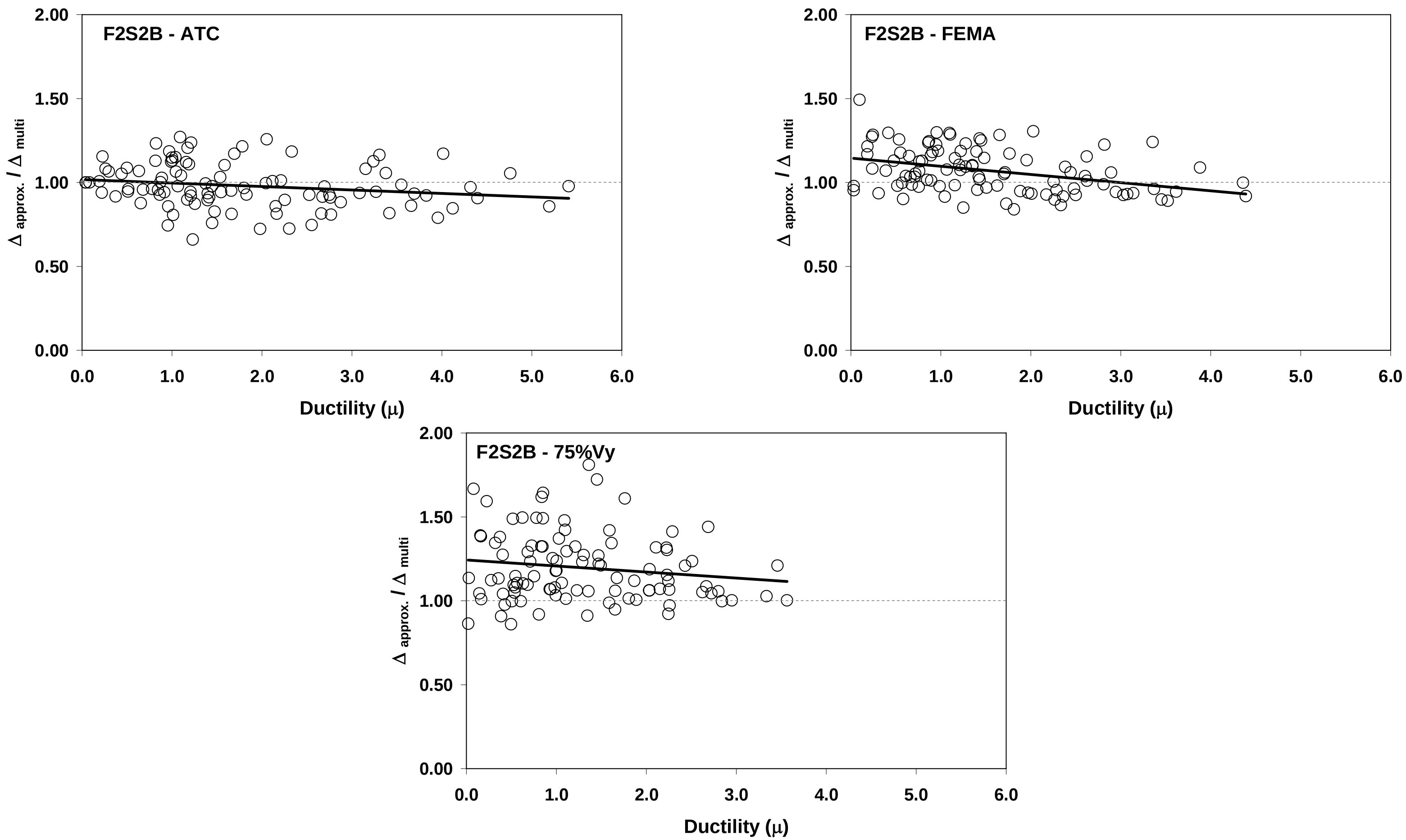


Figure A.7.43 Dependency on Ductility (Frame ‘F2S2B’ – Maximum Top Displacement)

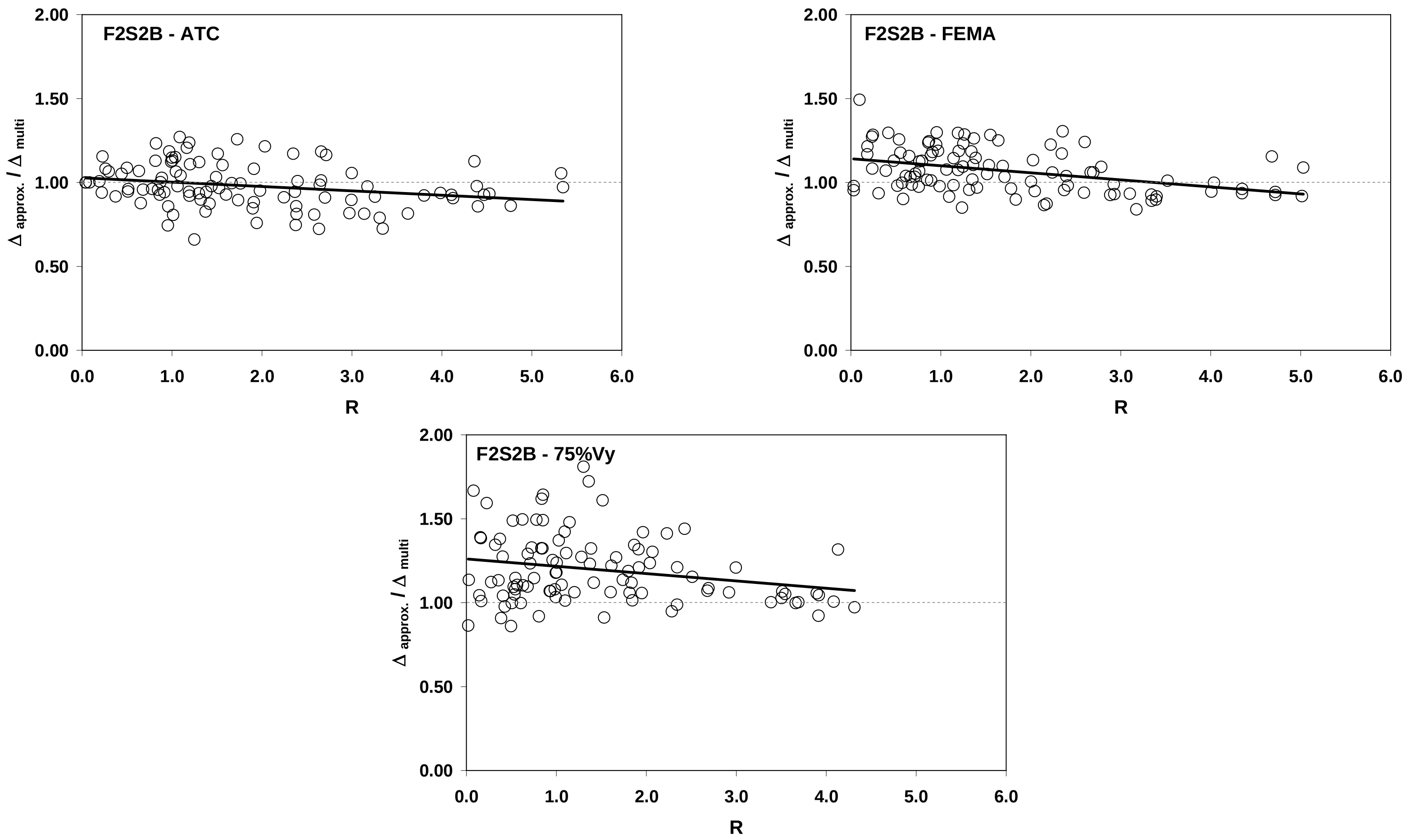


Figure A.7.44 Dependency on Strength Reduction Factor (Frame ‘F2S2B’ – Maximum Top Displacement)

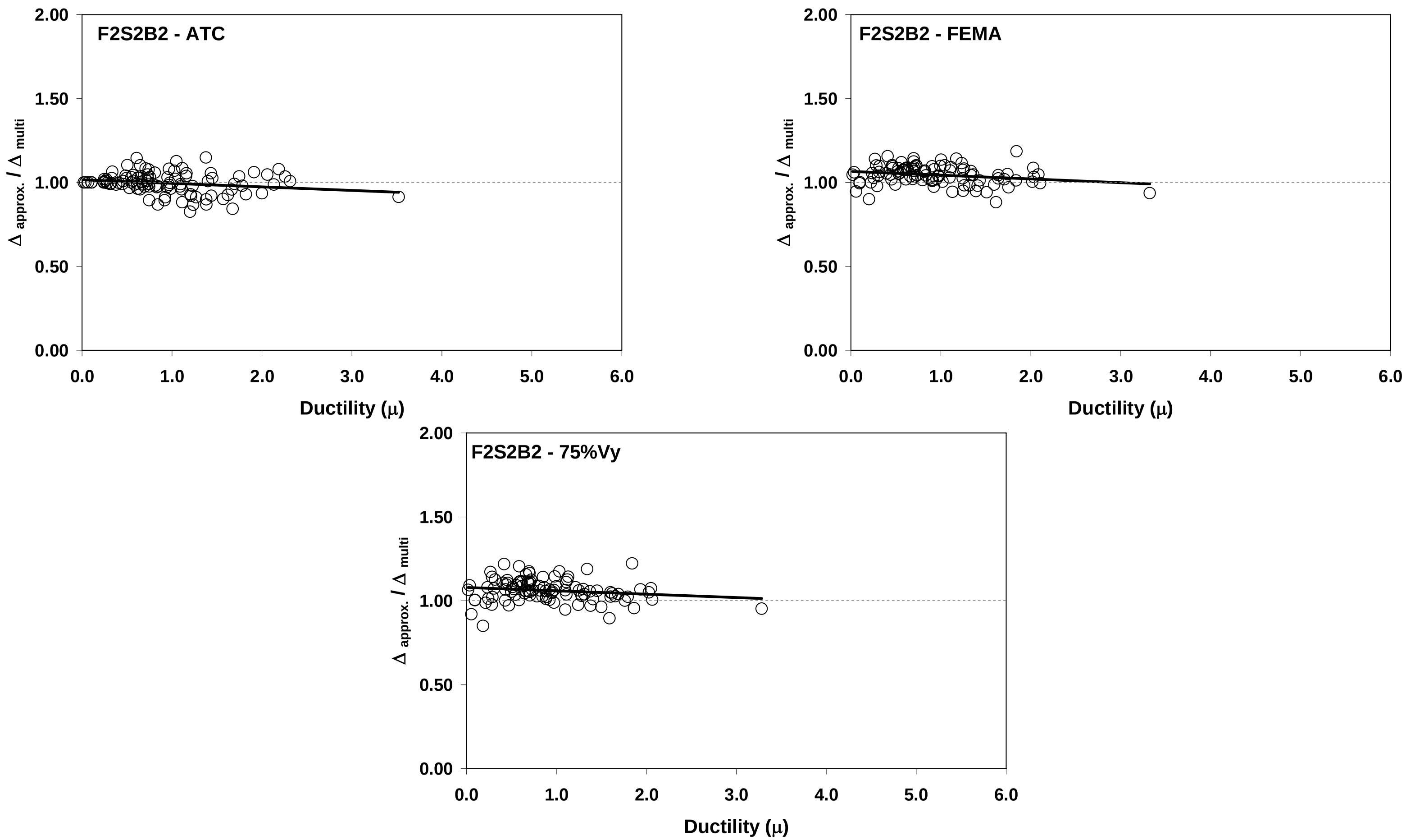


Figure A.7.45 Dependency on Ductility (Frame ‘F2S2B2’ – Maximum Top Displacement)

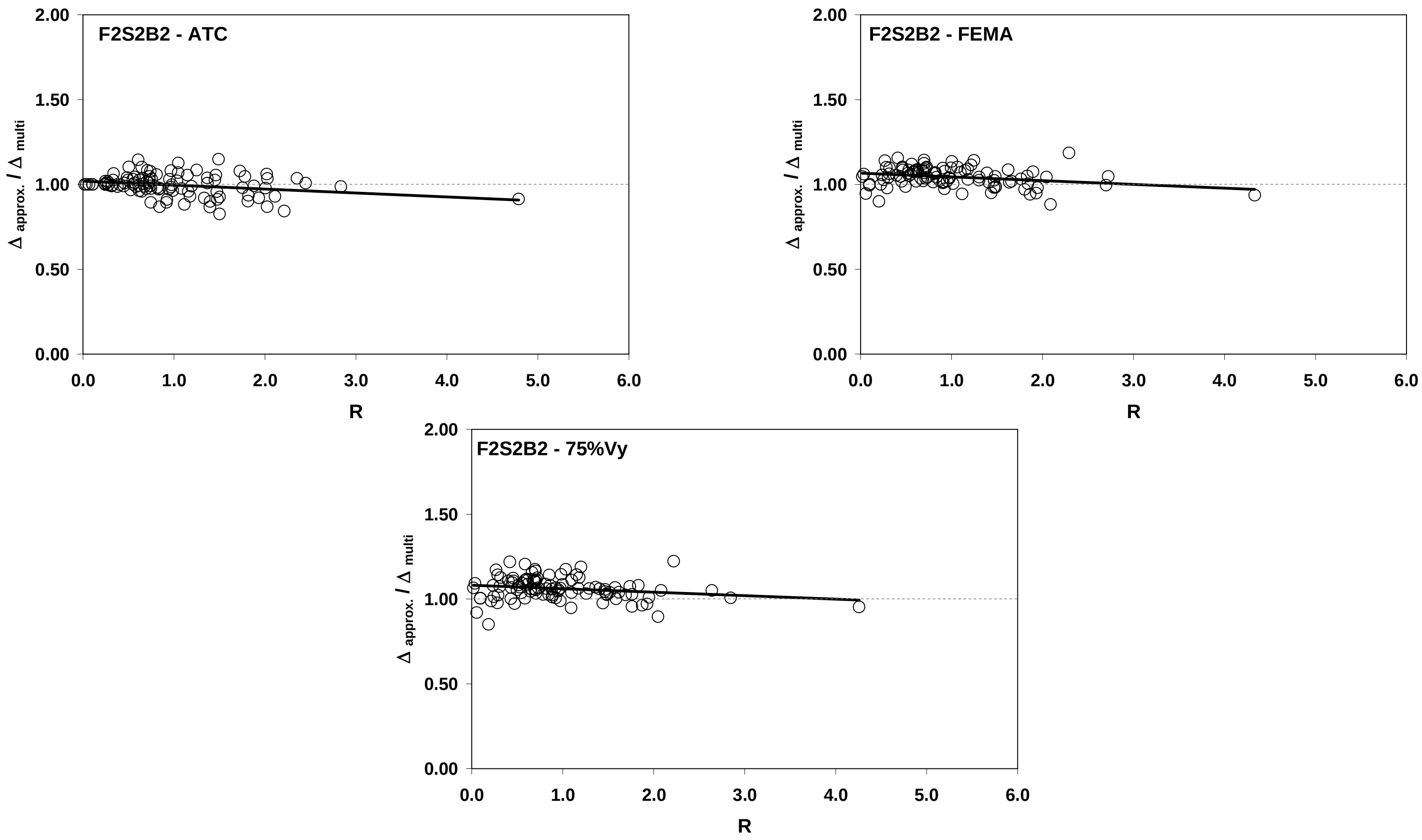


Figure A.7.46 Dependency on Strength Reduction Factor (Frame ‘F2S2B2’ – Maximum Top Displacement)

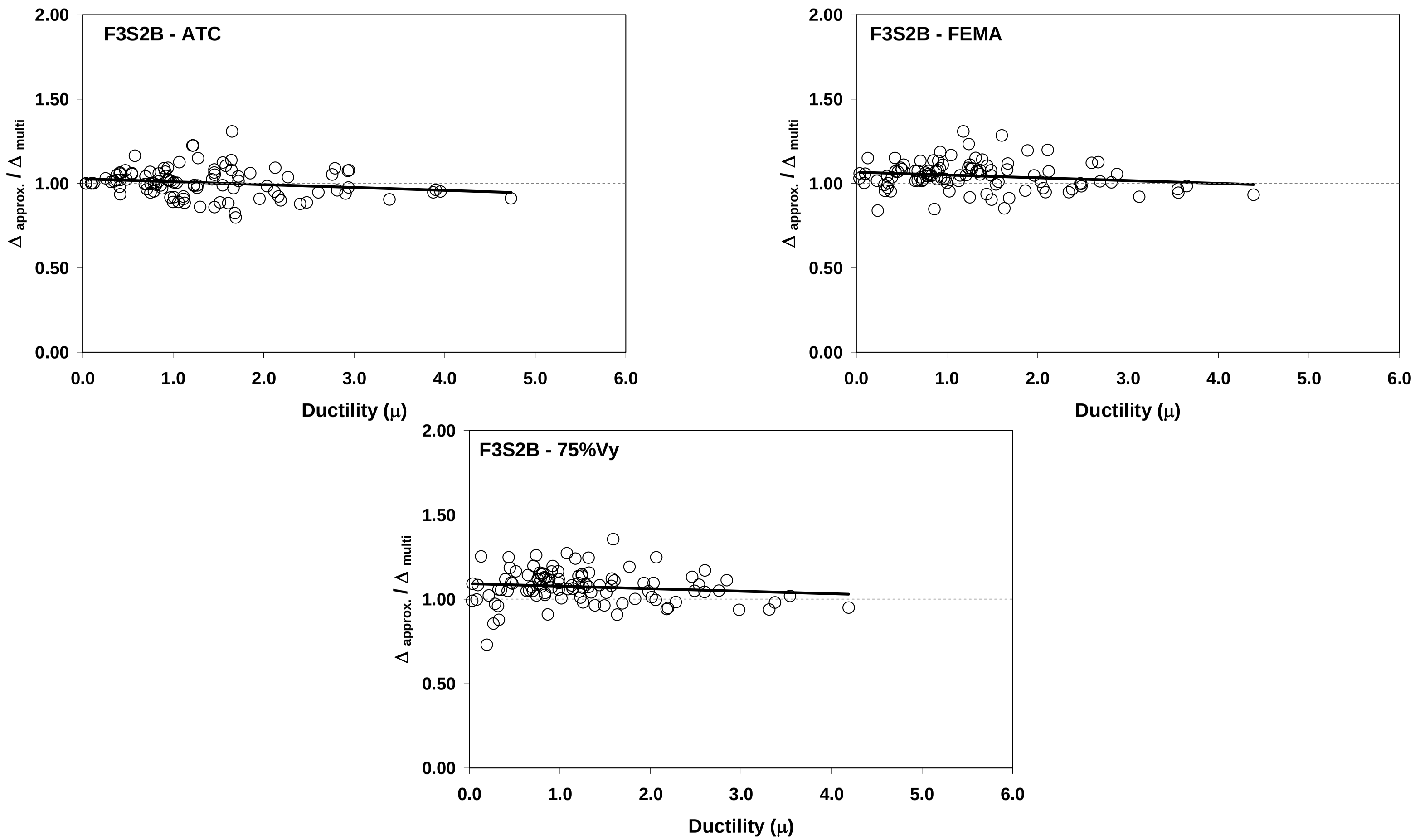


Figure A.7.47 Dependency on Ductility (Frame ‘F3S2B’ – Maximum Top Displacement)

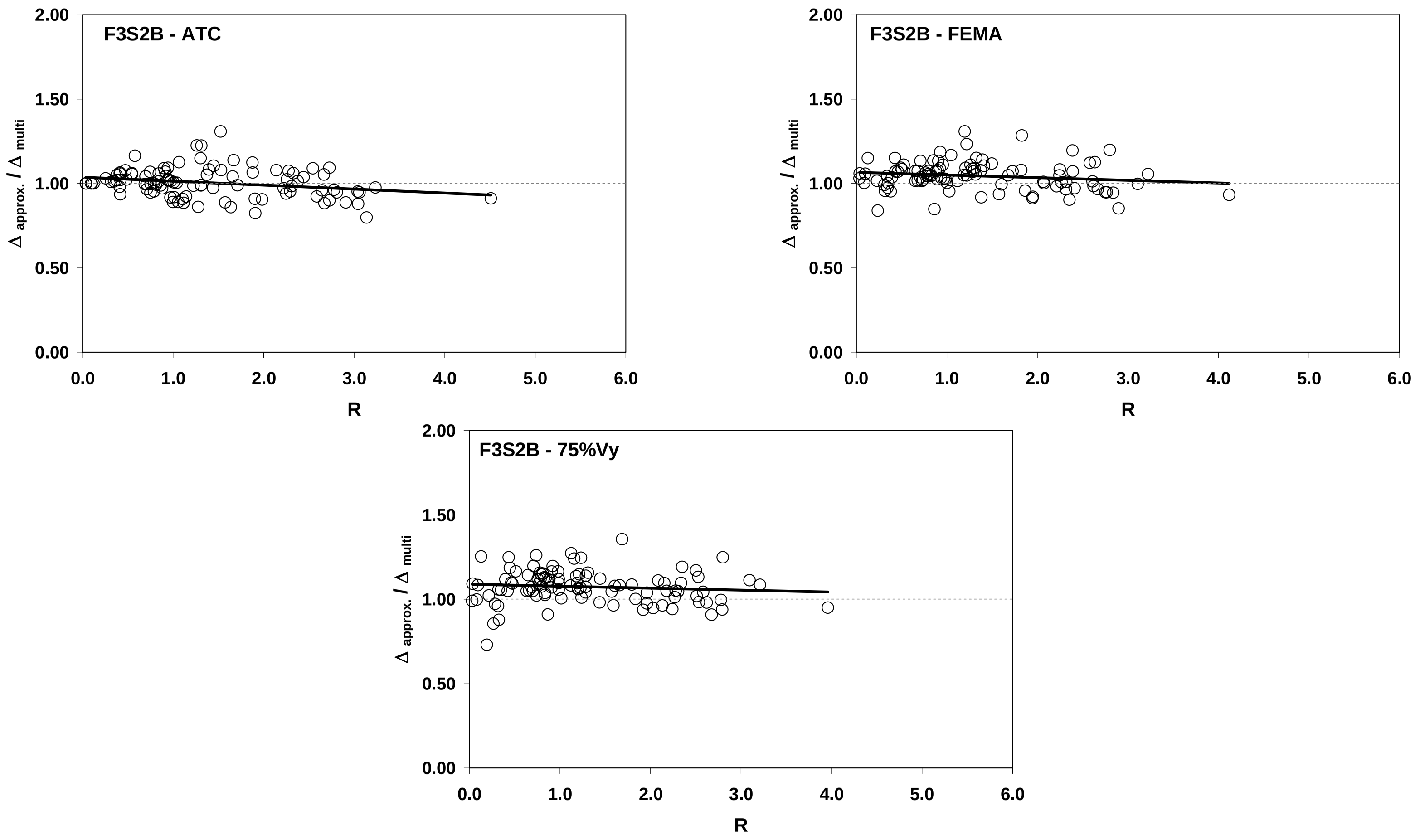


Figure A.7.48 Dependency on Strength Reduction Factor (Frame ‘F3S2B’ – Maximum Top Displacement)

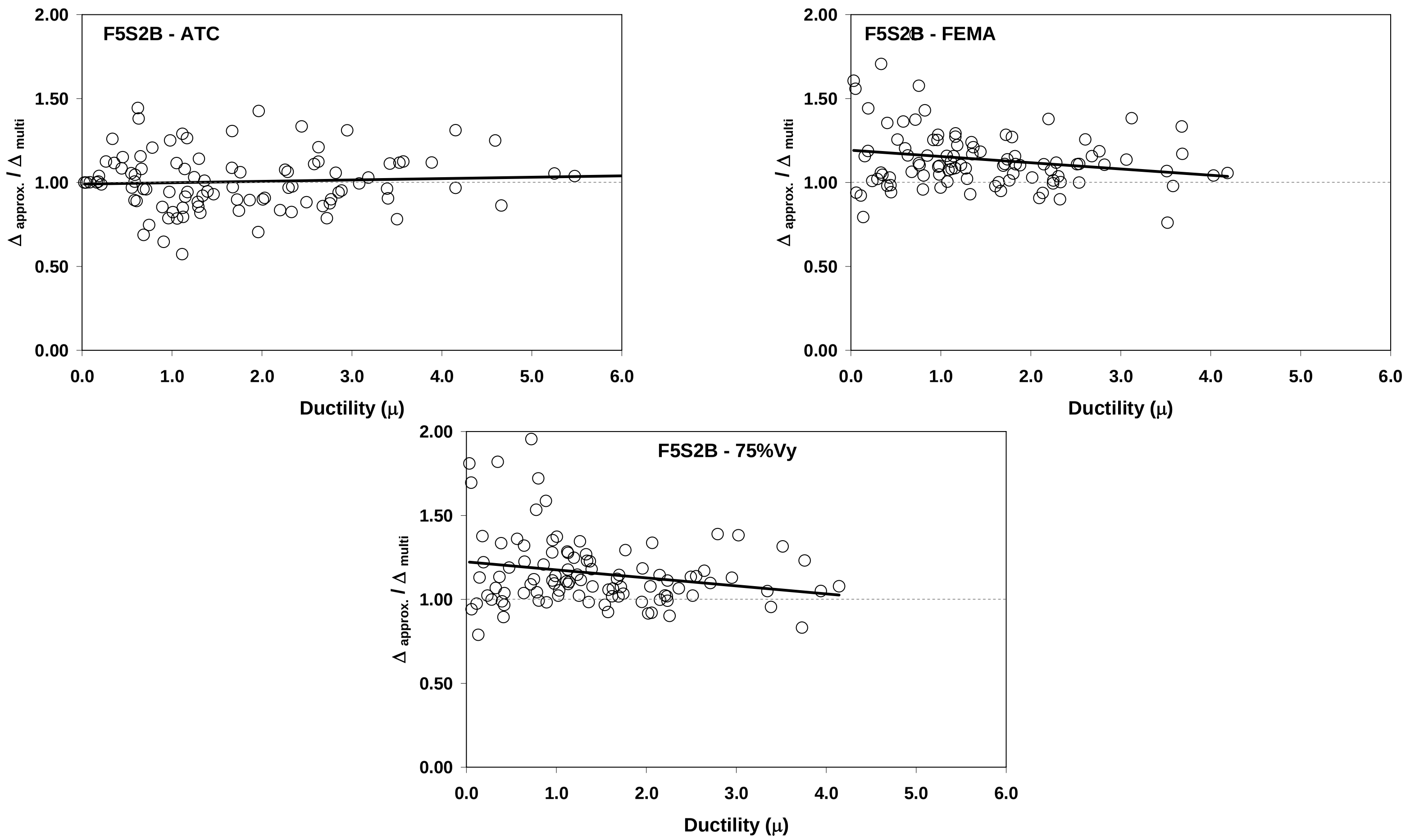


Figure A.7.49 Dependency on Ductility (Frame ‘F5S2B’ – Maximum Top Displacement)

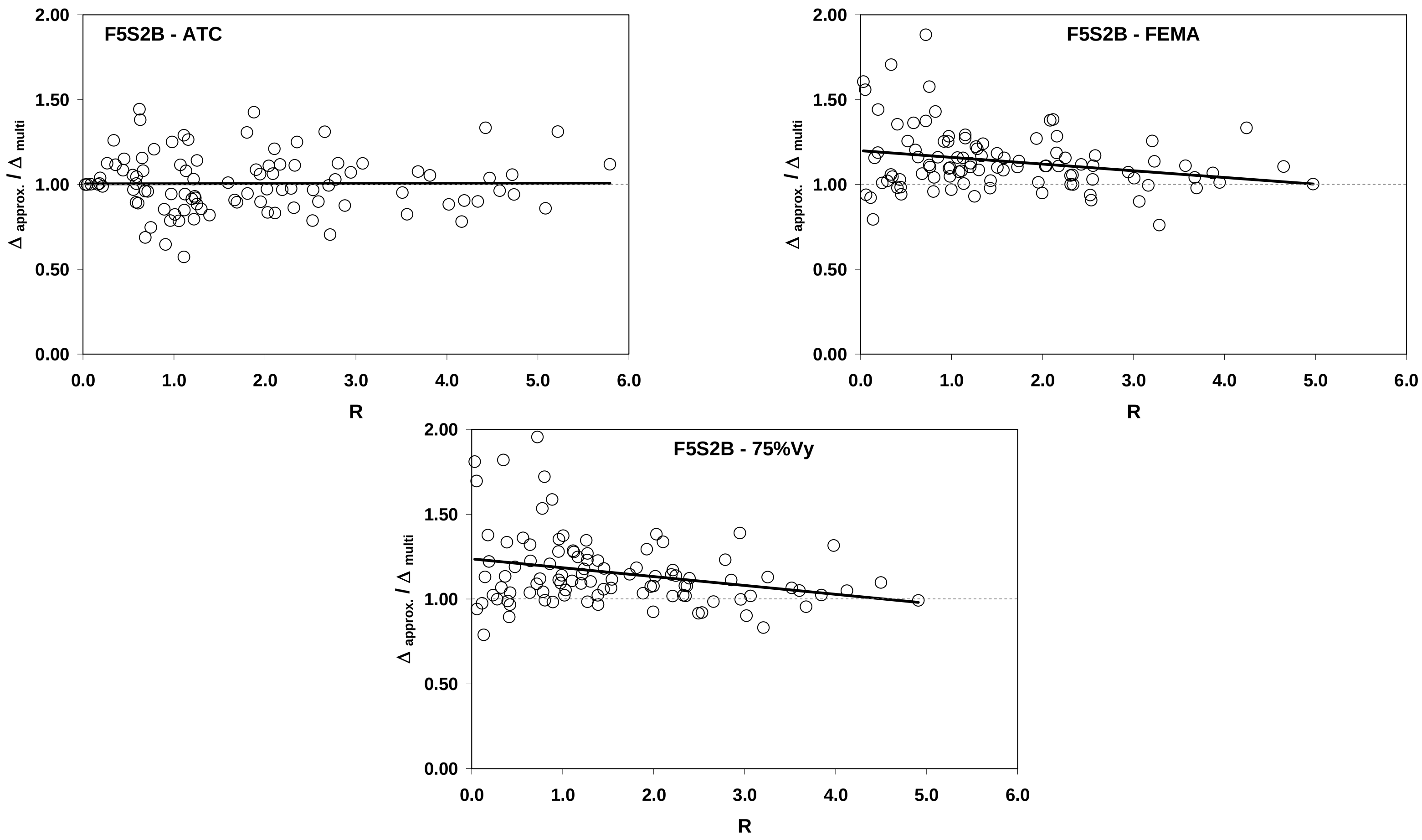


Figure A.7.50 Dependency on Strength Reduction Factor (Frame ‘F5S2B’ – Maximum Top Displacement)

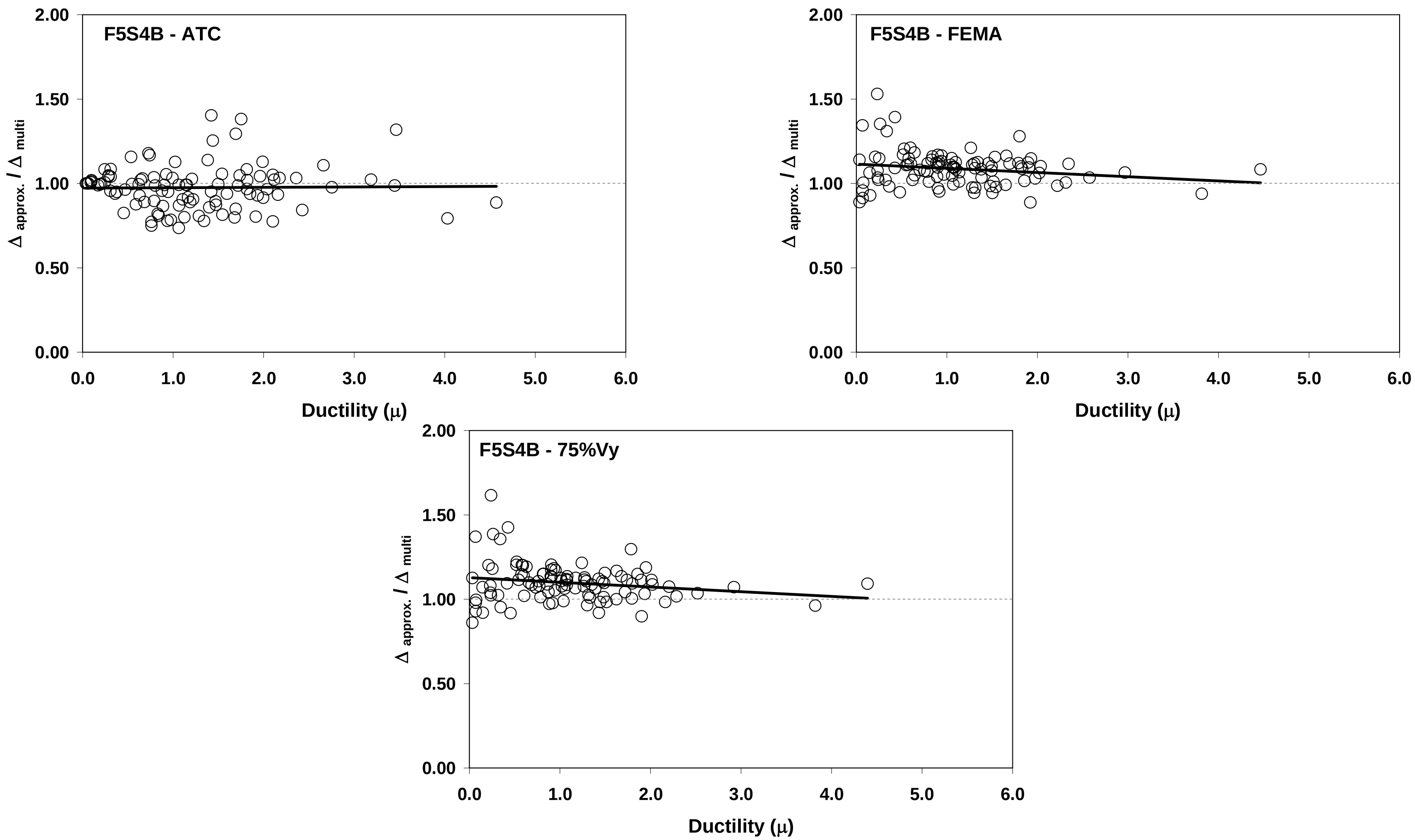


Figure A.7.51 Dependency on Ductility (Frame ‘F5S4B’ – Maximum Top Displacement)

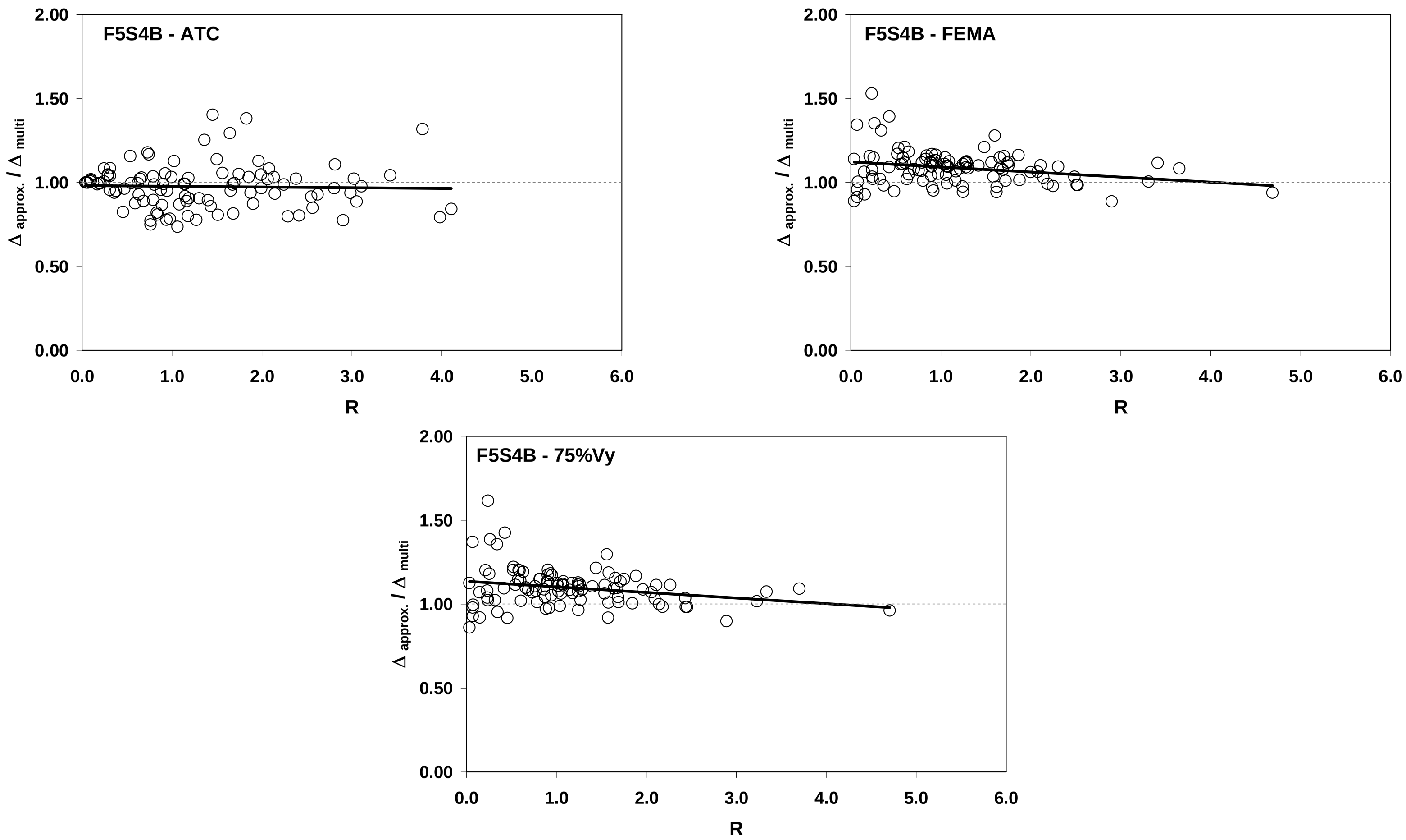


Figure A.7.52 Dependency on Strength Reduction Factor (Frame ‘F5S4B’ – Maximum Top Displacement)

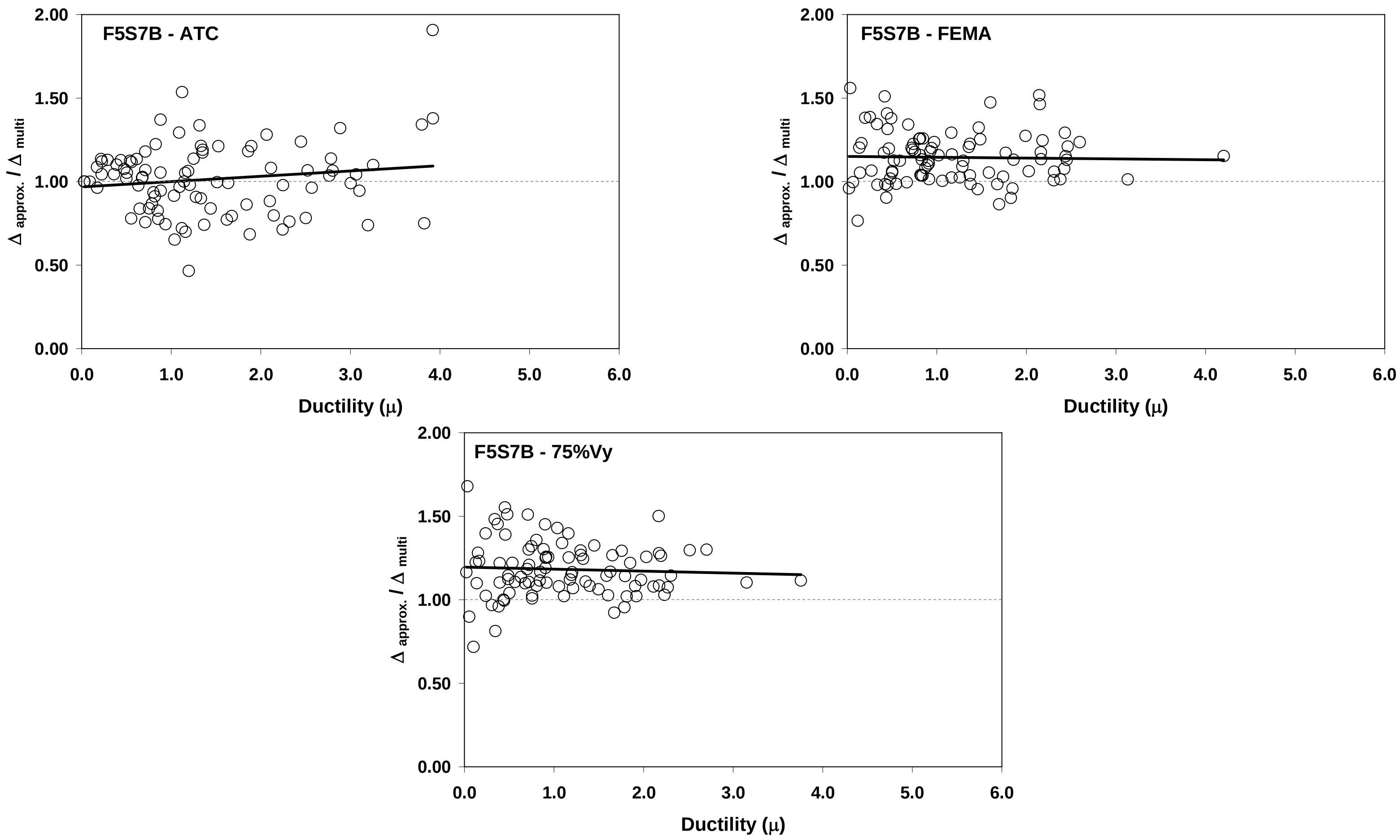


Figure A.7.53 Dependency on Ductility (Frame ‘F5S7B’ – Maximum Top Displacement)

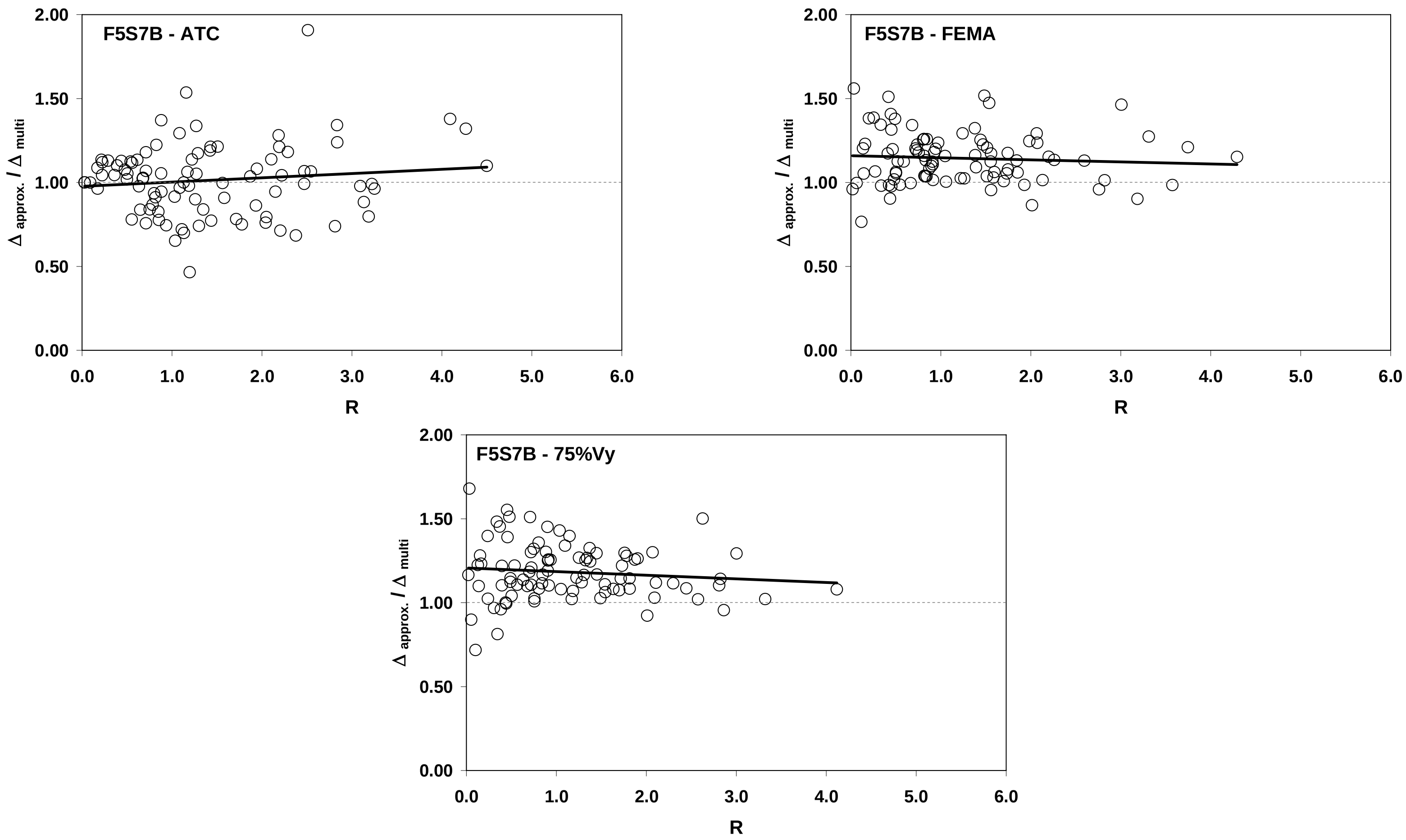


Figure A.7.54 Dependency on Strength Reduction Factor (Frame ‘F5S7B’ – Maximum Top Displacement)

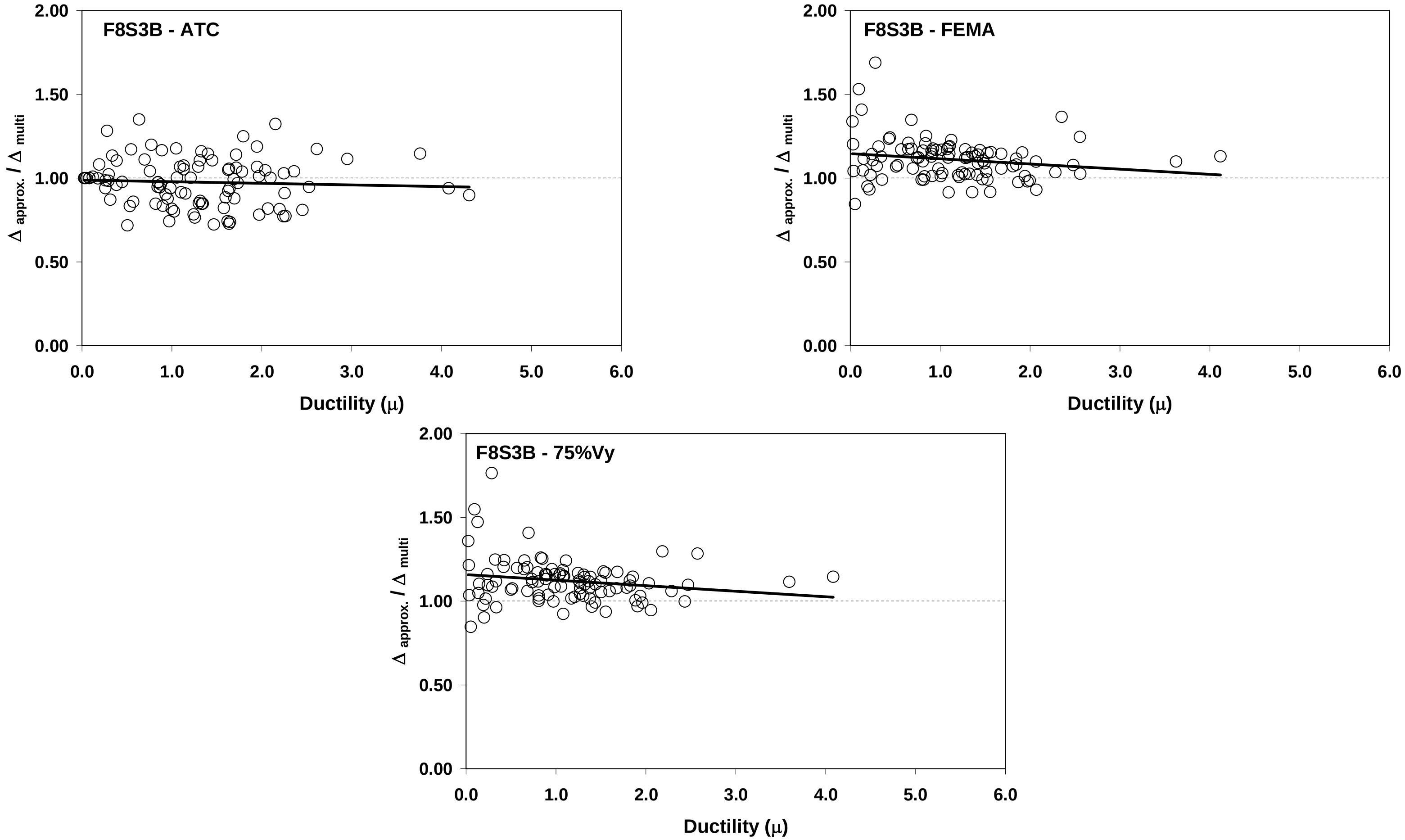


Figure A.7.55 Dependency on Ductility (Frame ‘F8S3B’ – Maximum Top Displacement)

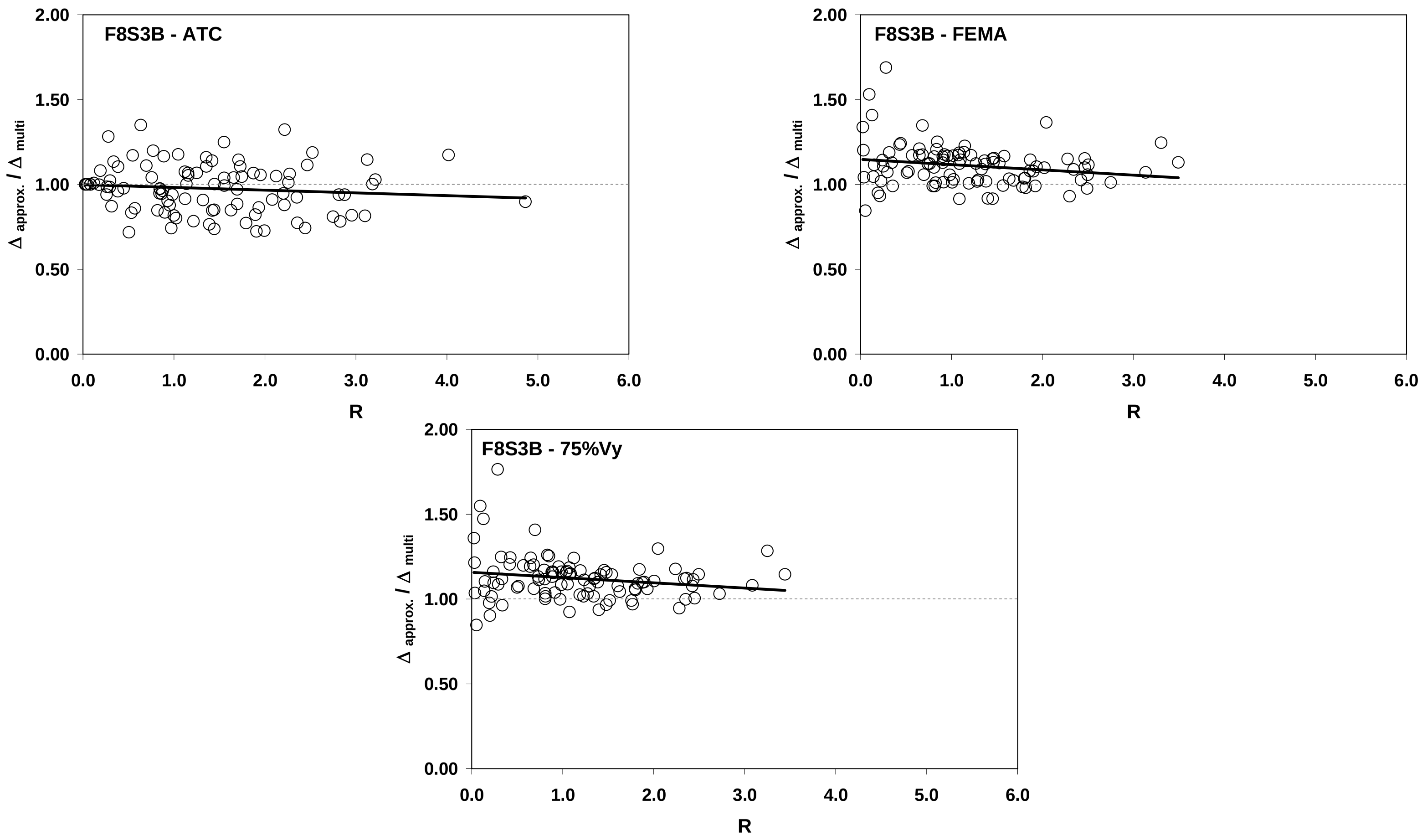


Figure A.7.56 Dependency on Strength Reduction Factor (Frame ‘F8S3B’ – Maximum Top Displacement)

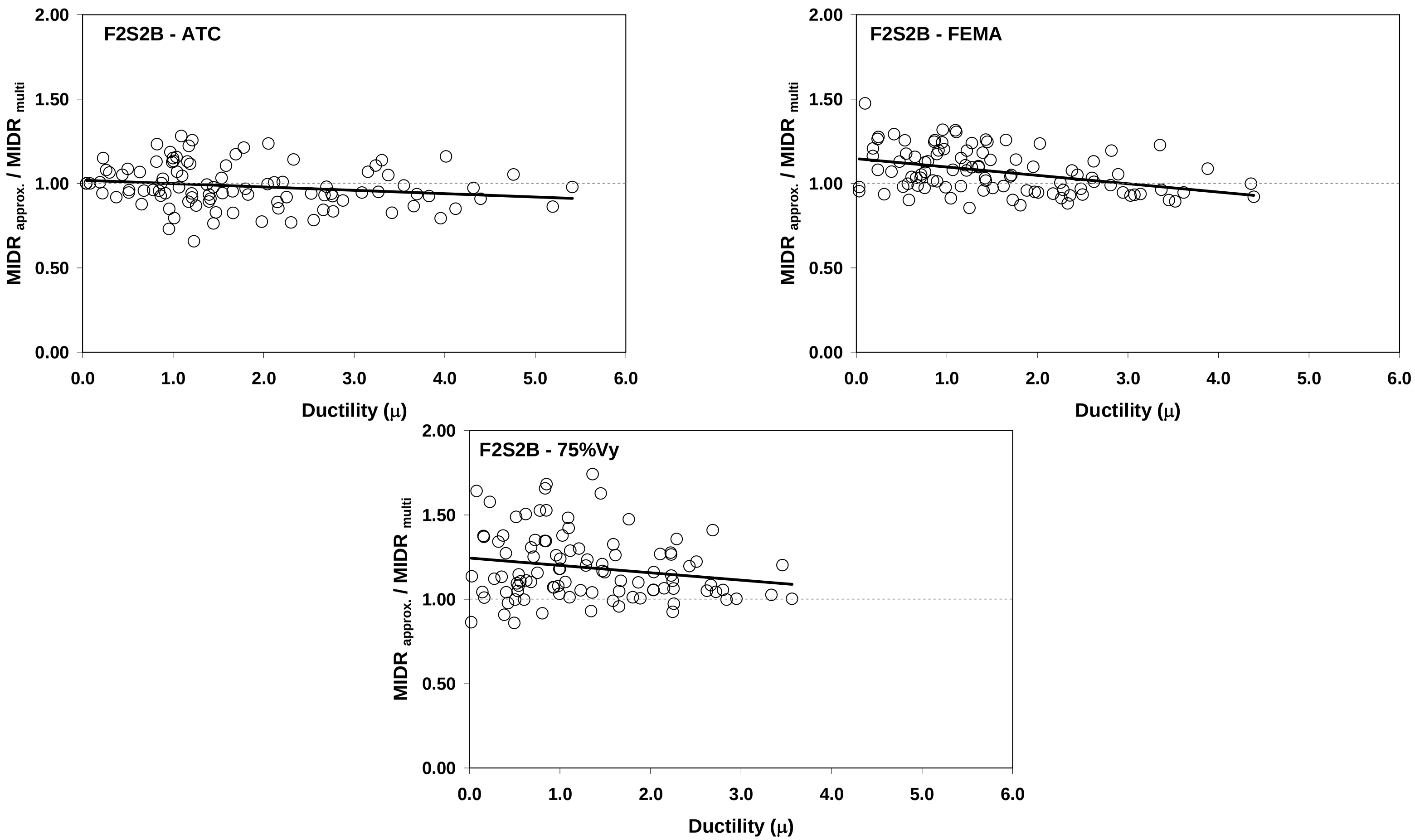


Figure A.7.57 Dependency on Ductility (Frame ‘F2S2B’ – Maximum Inter-Story Drift Ratio)

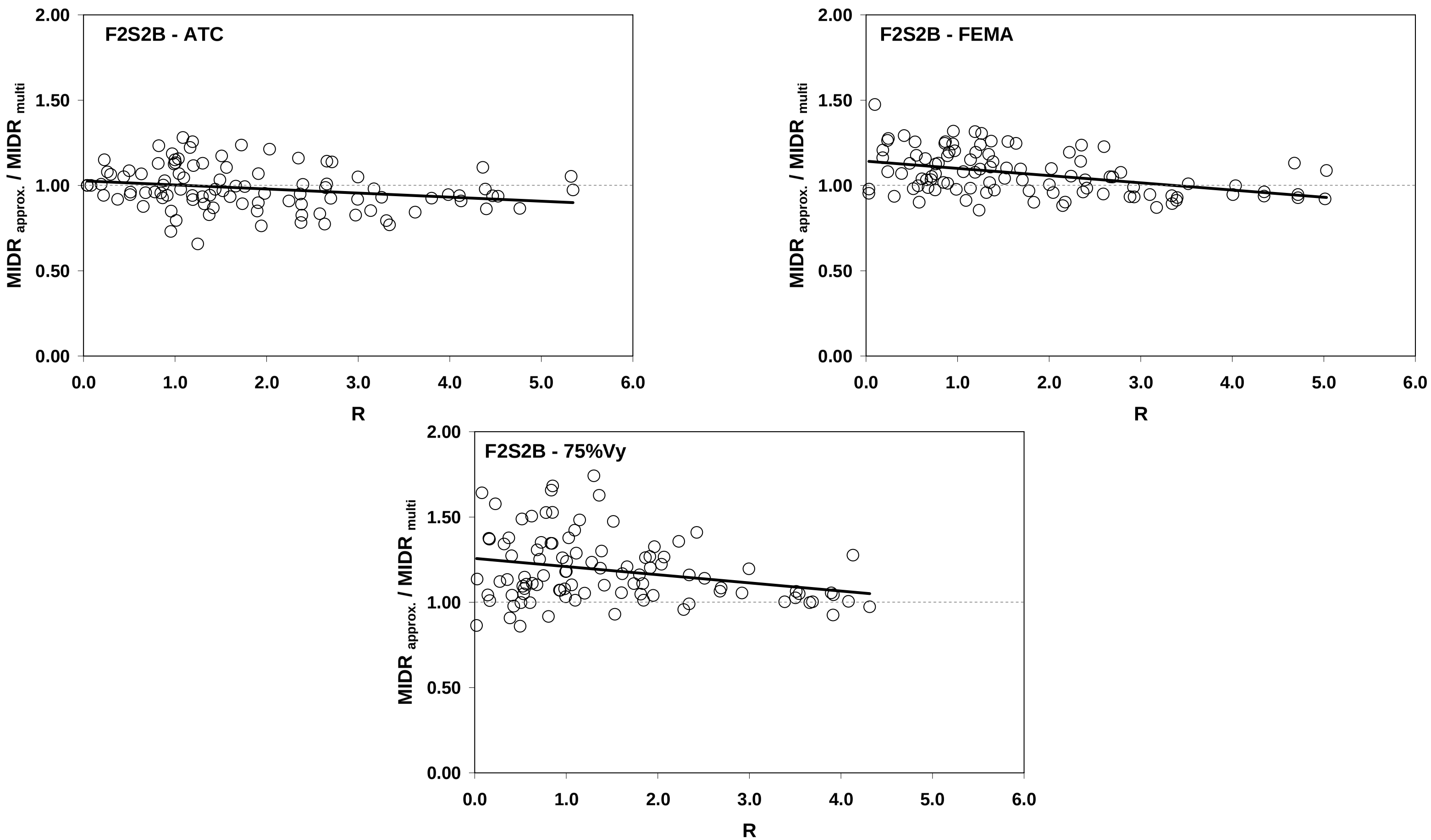


Figure A.7.58 Dependency on Strength Reduction Factor (Frame ‘F2S2B’ – Maximum Inter-Story Drift Ratio)

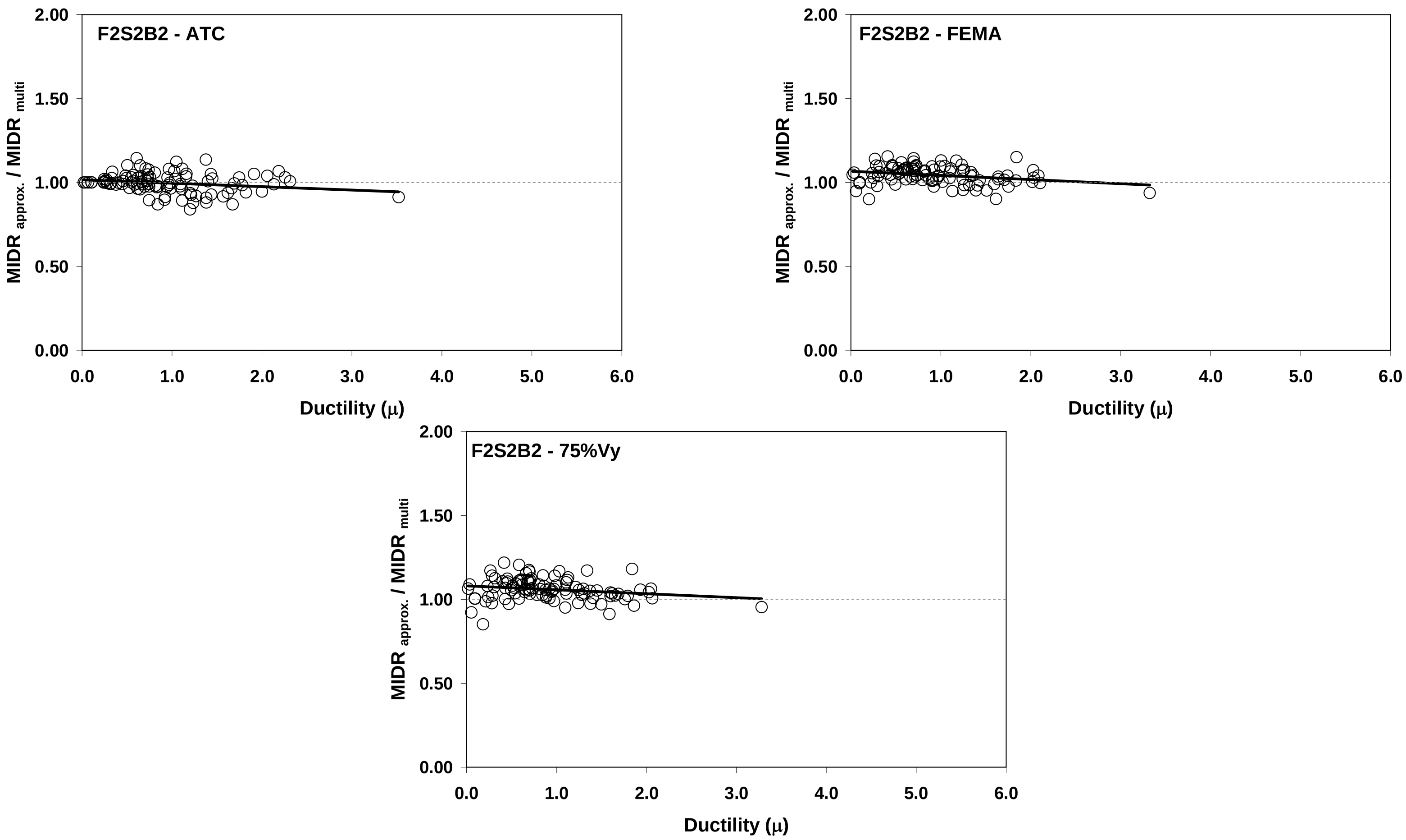


Figure A.7.59 Dependency on Ductility (Frame 'F2S2B2' – Maximum Inter-Story Drift Ratio)

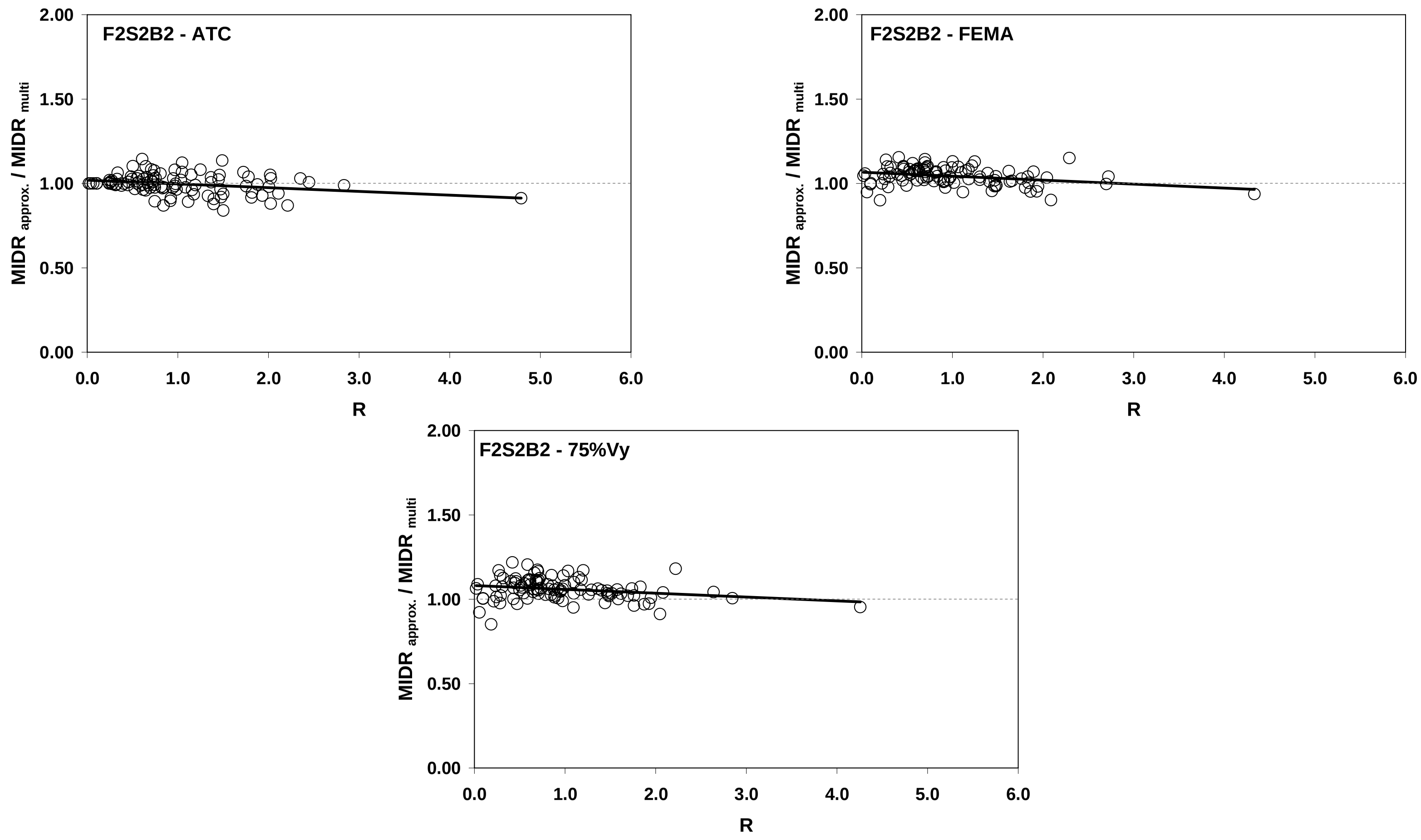


Figure A.7.60 Dependency on Strength Reduction Factor (Frame ‘F2S2B2’ – Maximum Inter-Story Drift Ratio)

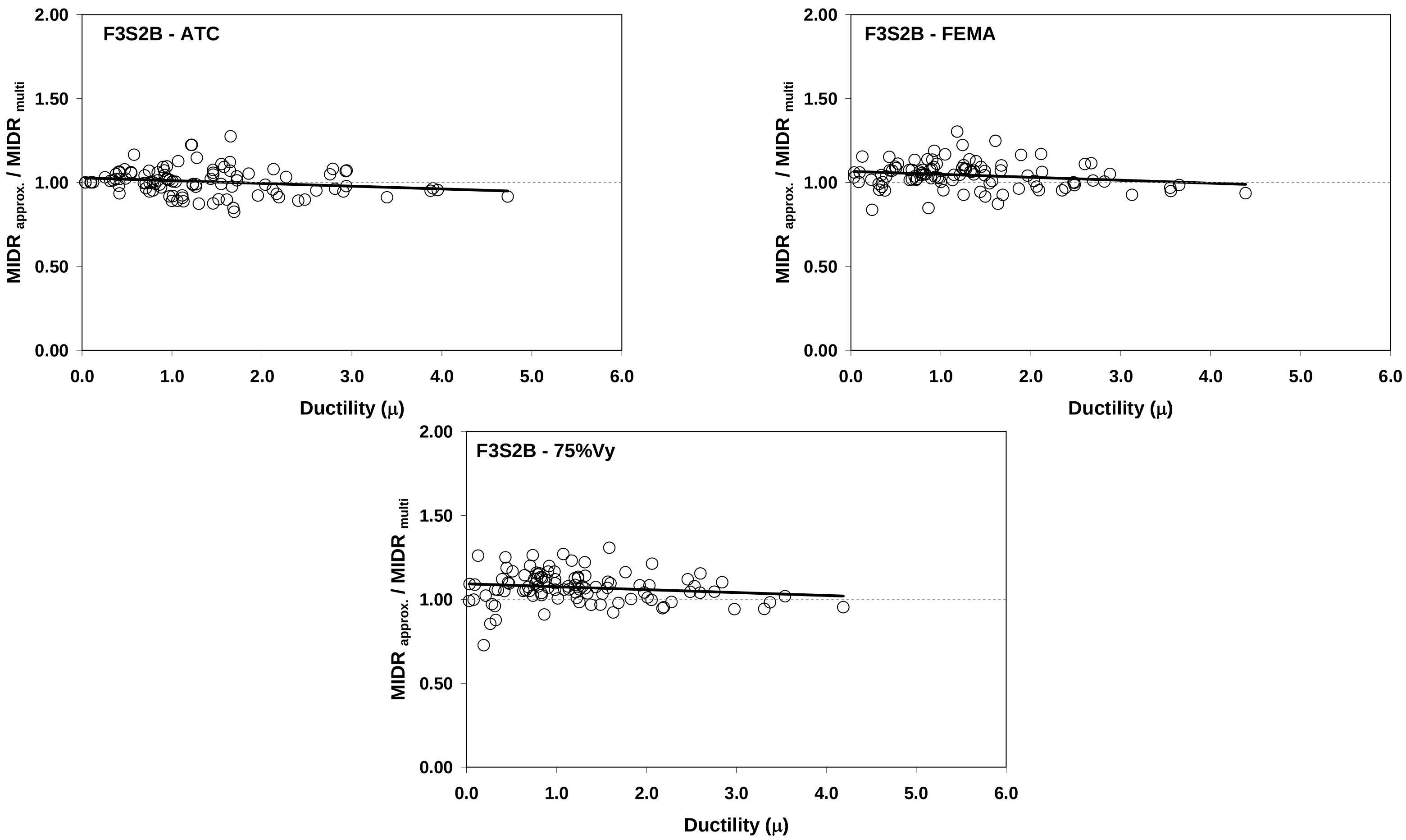


Figure A.7.61 Dependency on Ductility (Frame ‘F3S2B’ – Maximum Inter-Story Drift Ratio)

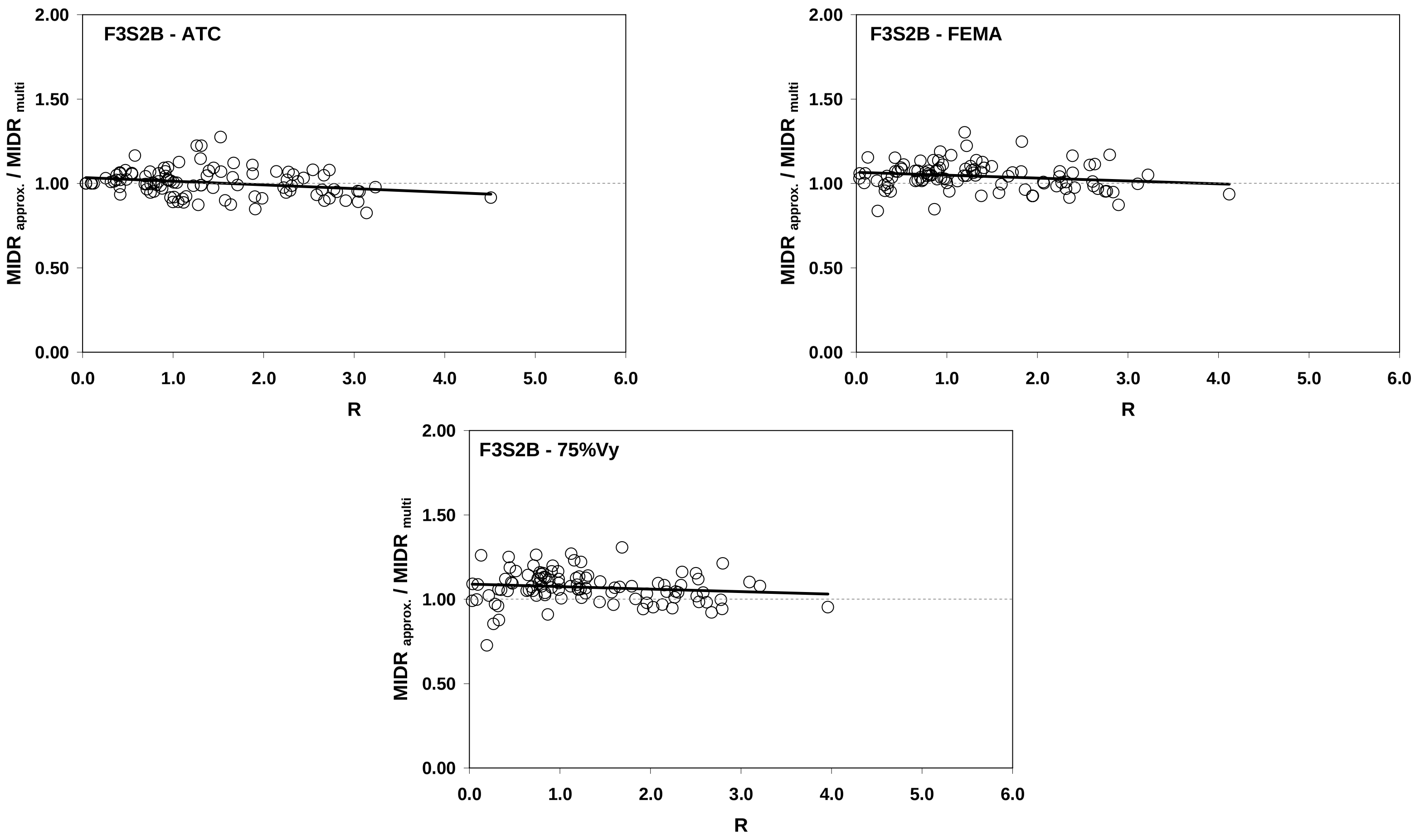


Figure A.7.62 Dependency on Strength Reduction Factor (Frame ‘F3S2B’ – Maximum Inter-Story Drift Ratio)

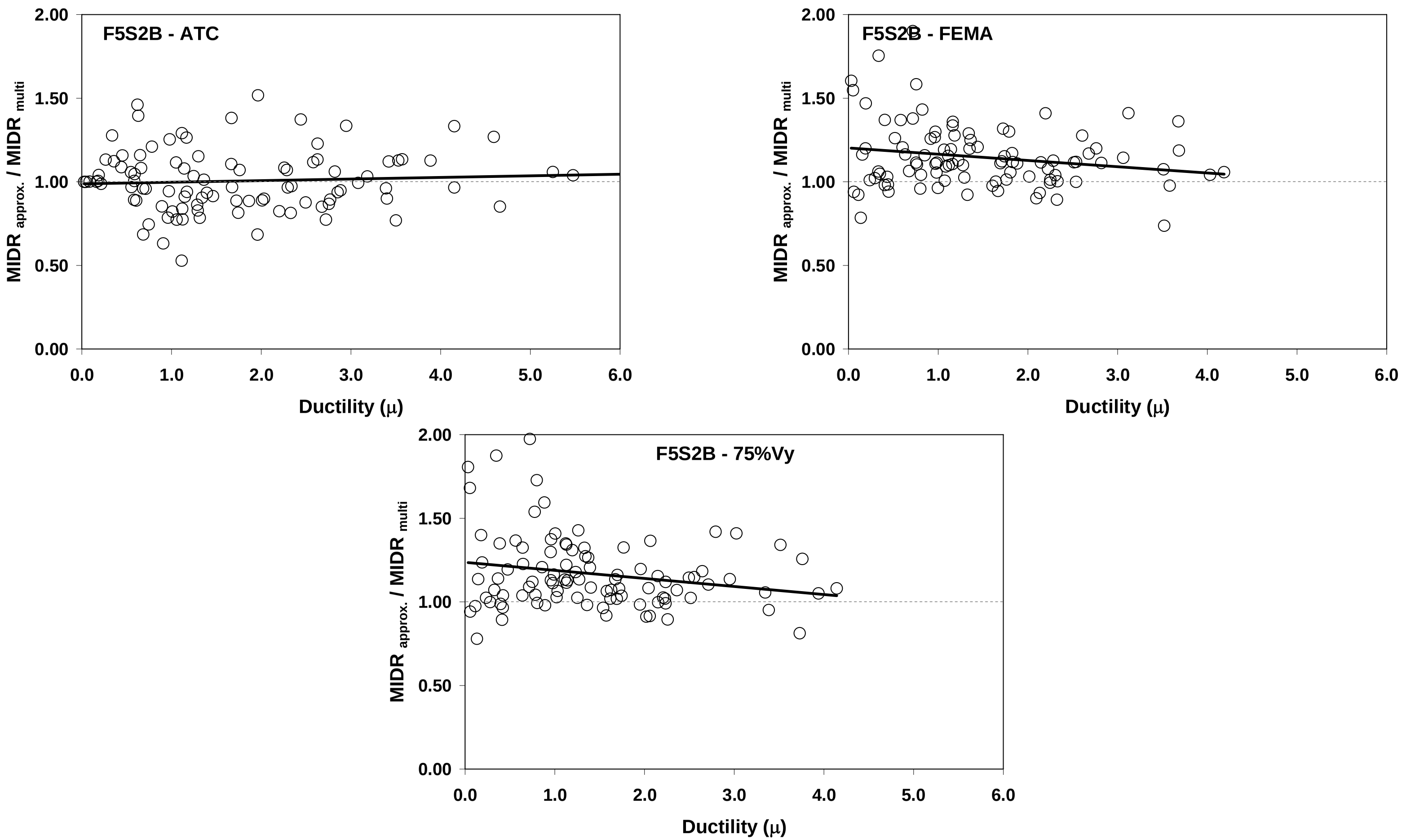


Figure A.7.63 Dependency on Ductility (Frame ‘F5S2B’ – Maximum Inter-Story Drift Ratio)

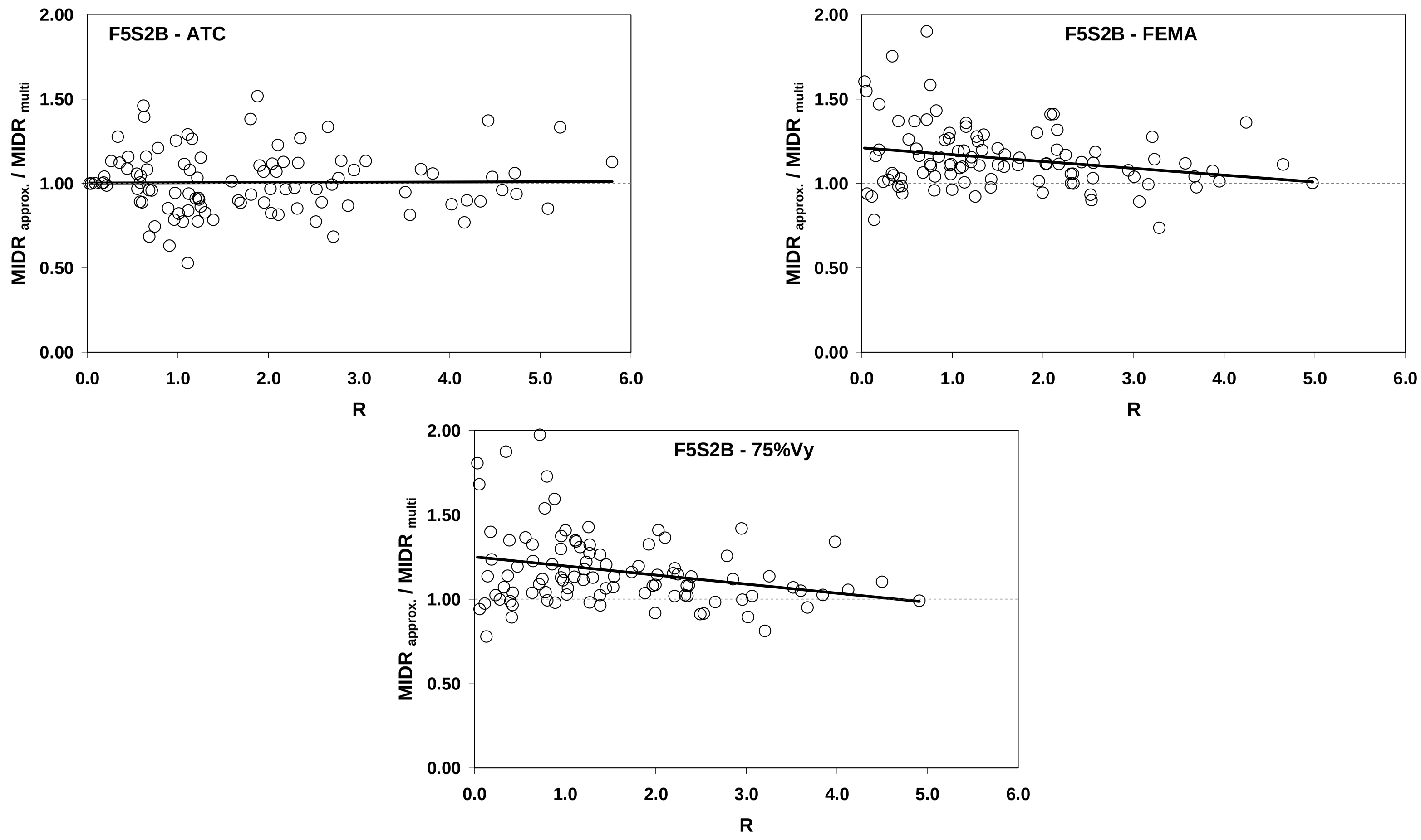


Figure A.7.64 Dependency on Strength Reduction Factor (Frame ‘F5S2B’ – Maximum Inter-Story Drift Ratio)

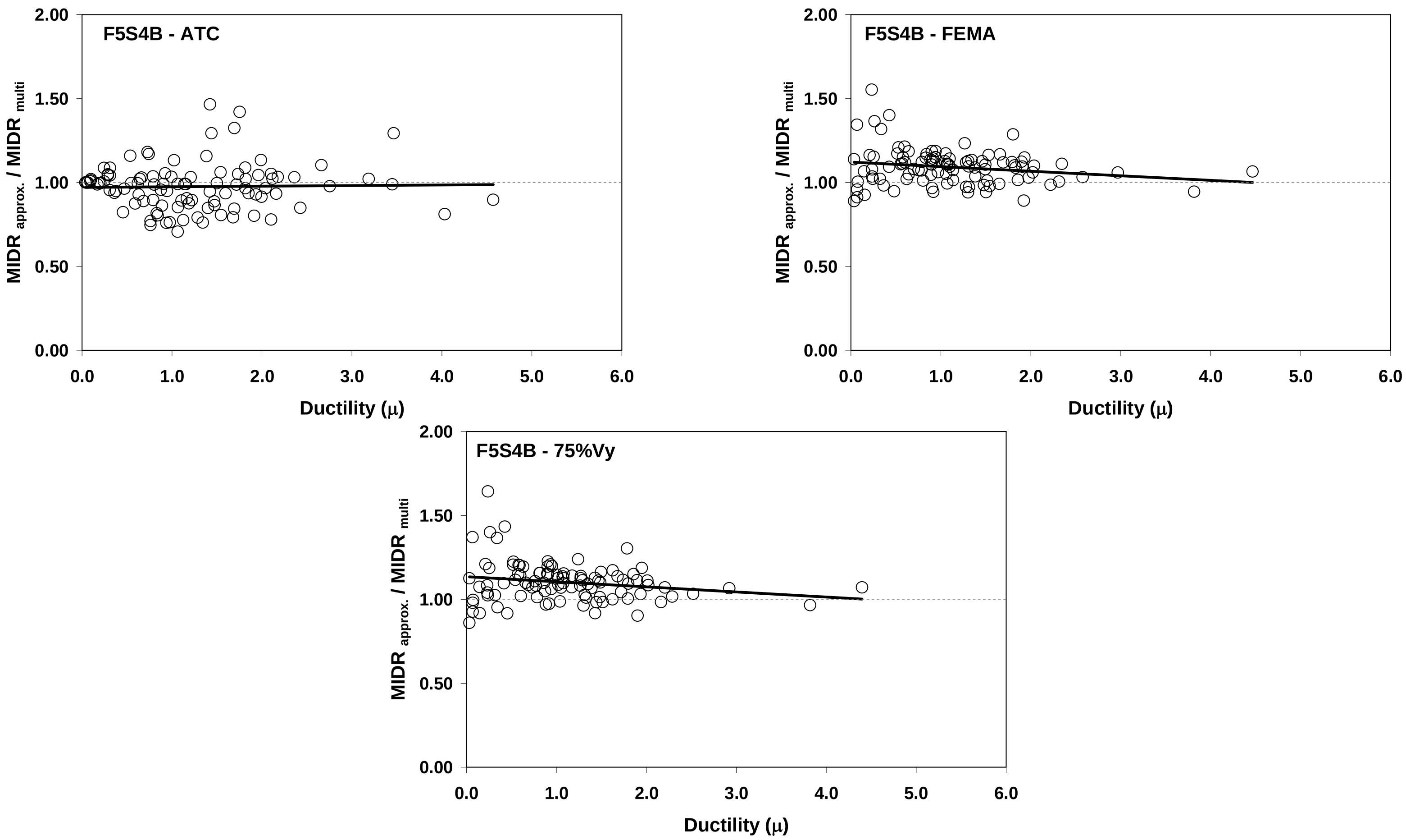


Figure A.7.65 Dependency on Ductility (Frame ‘F5S4B’ – Maximum Inter-Story Drift Ratio)

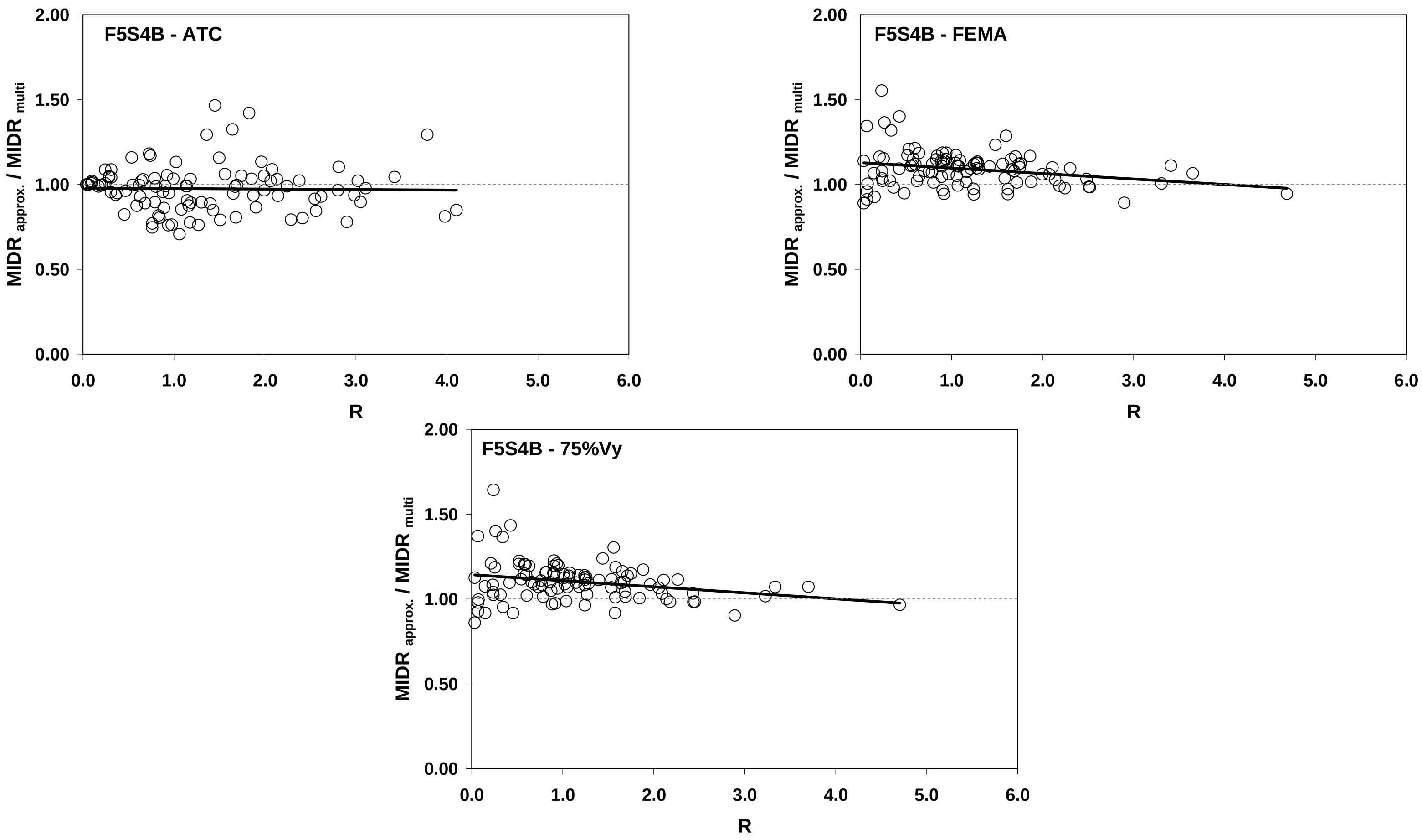


Figure A.7.66 Dependency on Strength Reduction Factor (Frame ‘F5S4B’ – Maximum Inter-Story Drift Ratio)

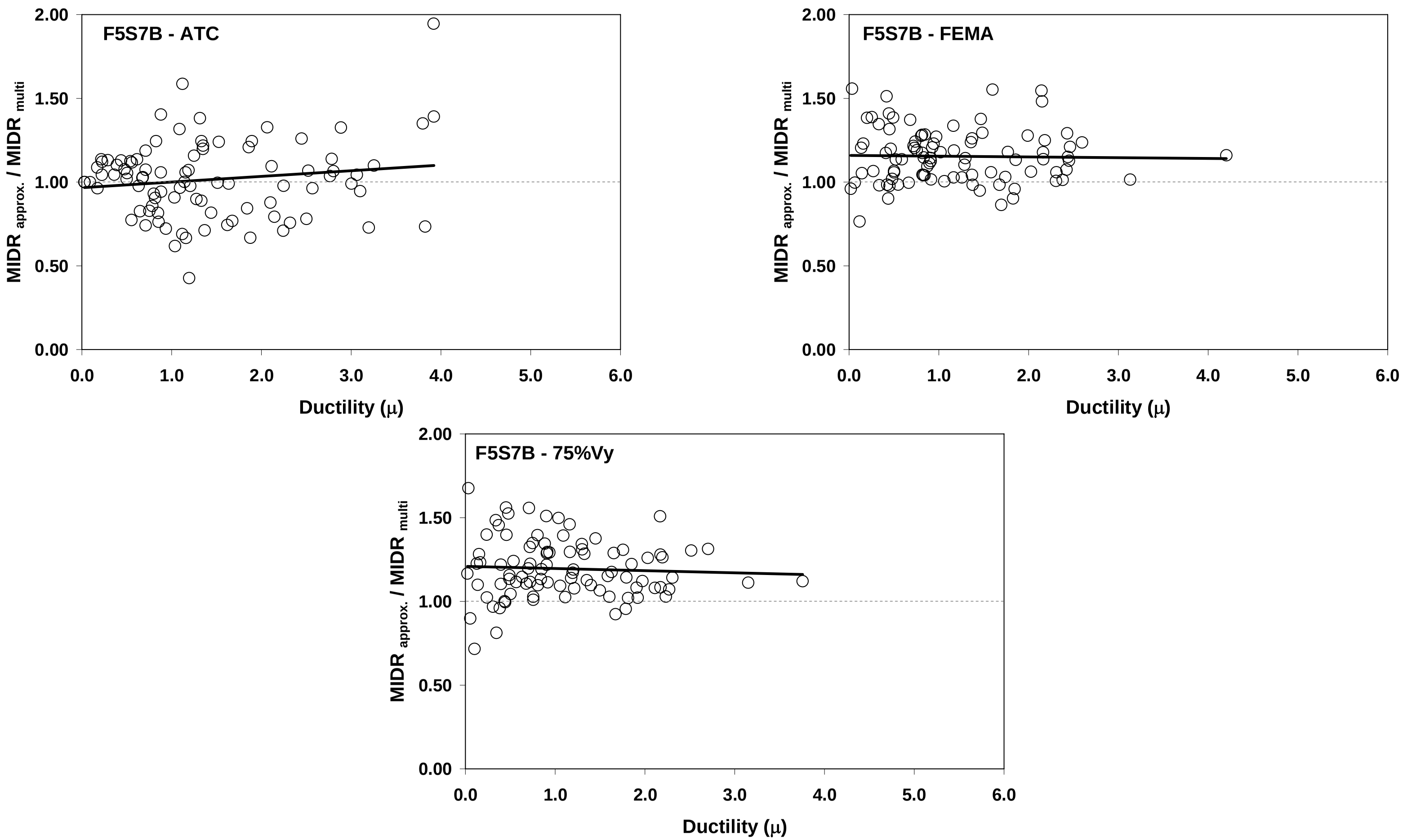


Figure A.7.67 Dependency on Ductility (Frame ‘F5S7B’ – Maximum Inter-Story Drift Ratio)

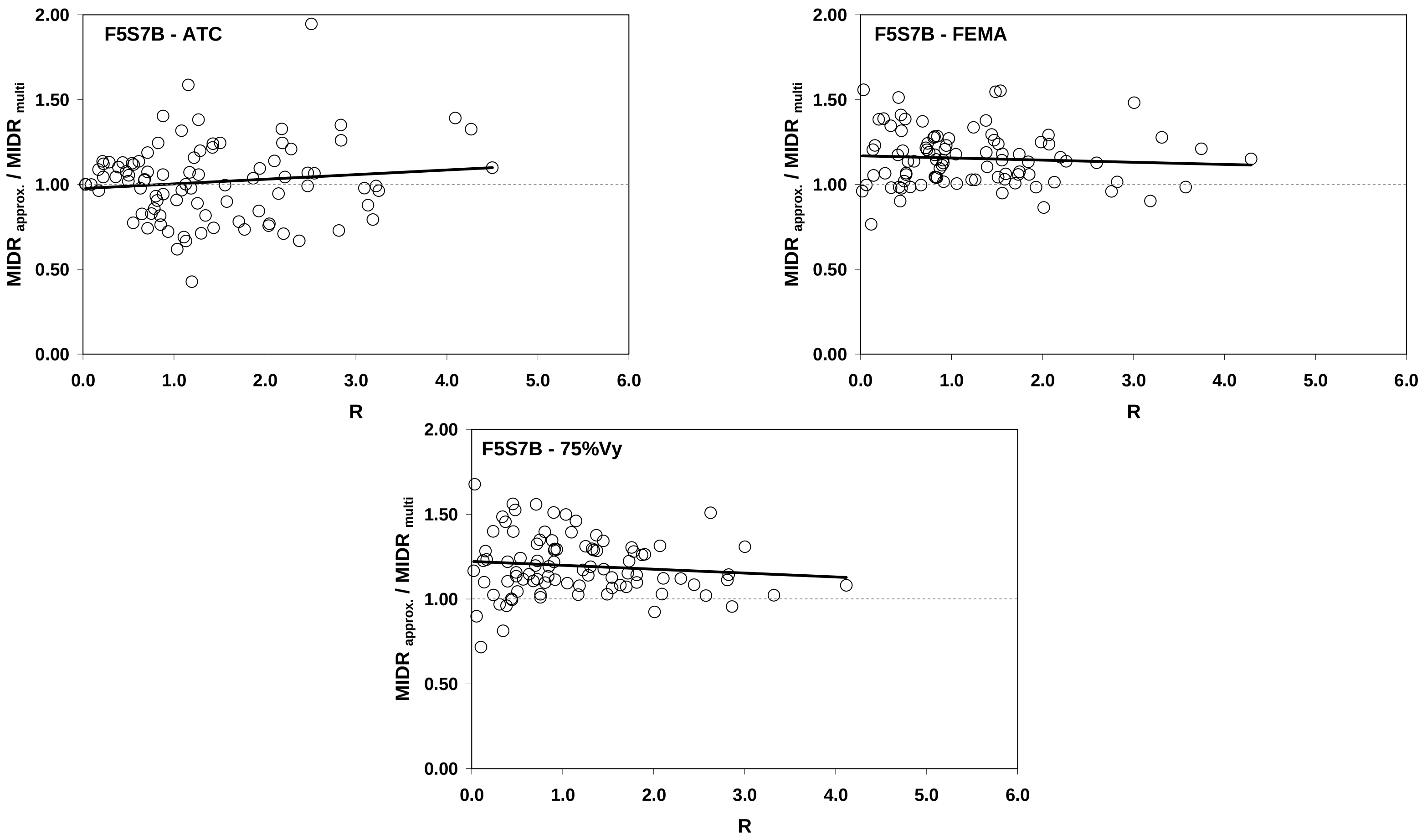


Figure A.7.68 Dependency on Strength Reduction Factor (Frame ‘F5S7B’ – Maximum Inter-Story Drift Ratio)

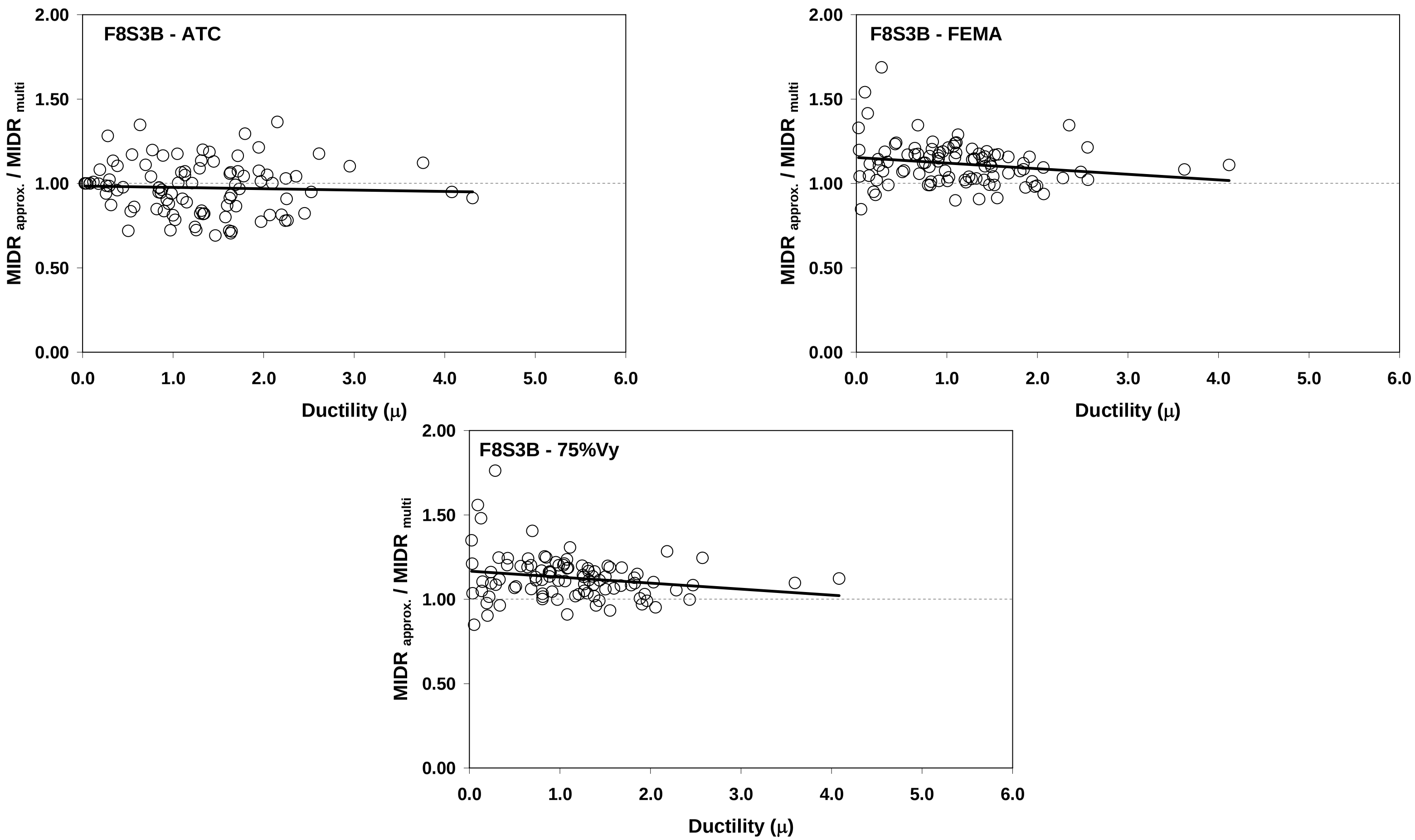


Figure A.7.69 Dependency on Ductility (Frame ‘F8S3B’ – Maximum Inter-Story Drift Ratio)

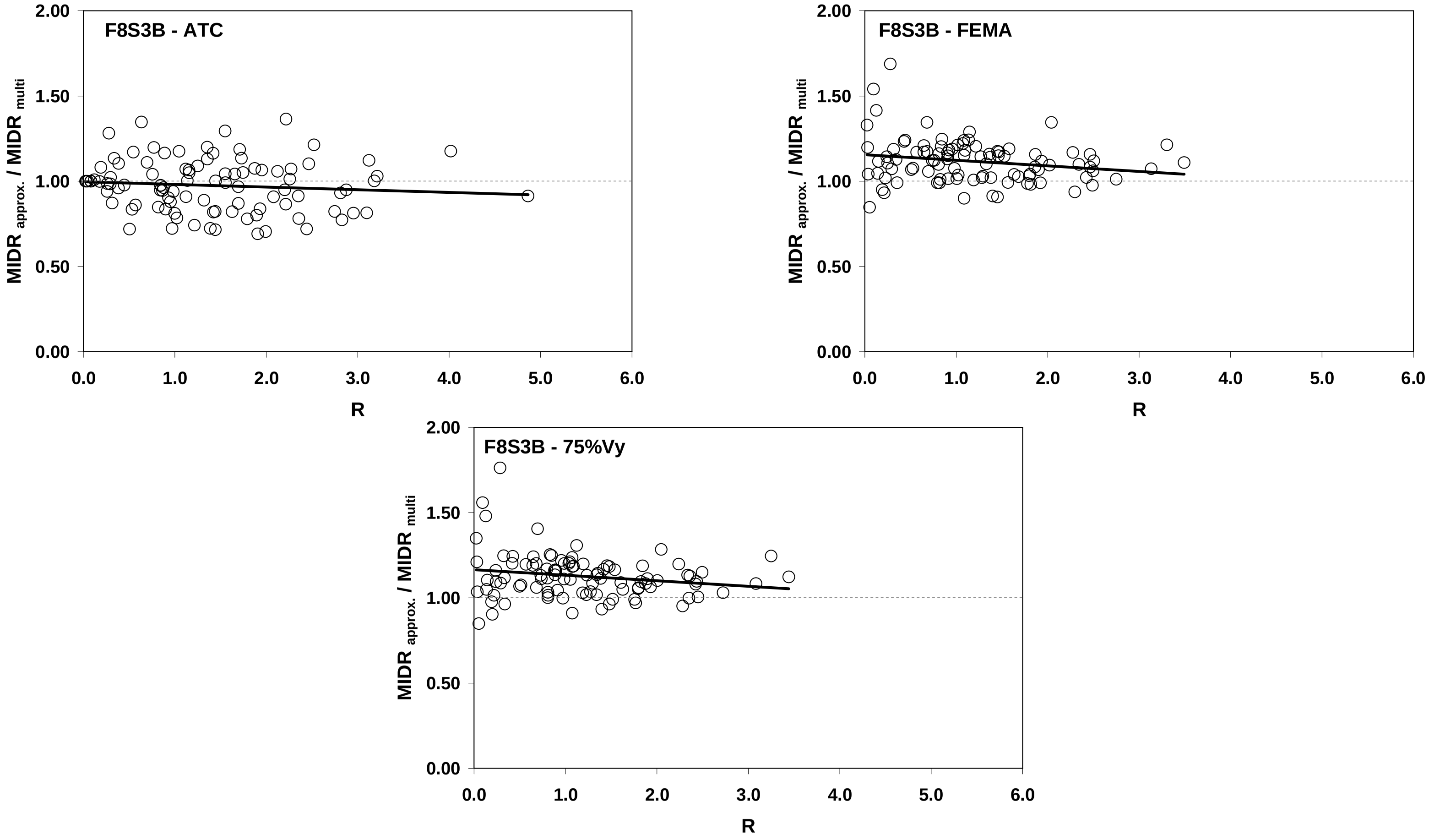


Figure A.7.70 Dependency on Strength Reduction Factor (Frame ‘F8S3B’ – Maximum Inter-Story Drift Ratio)

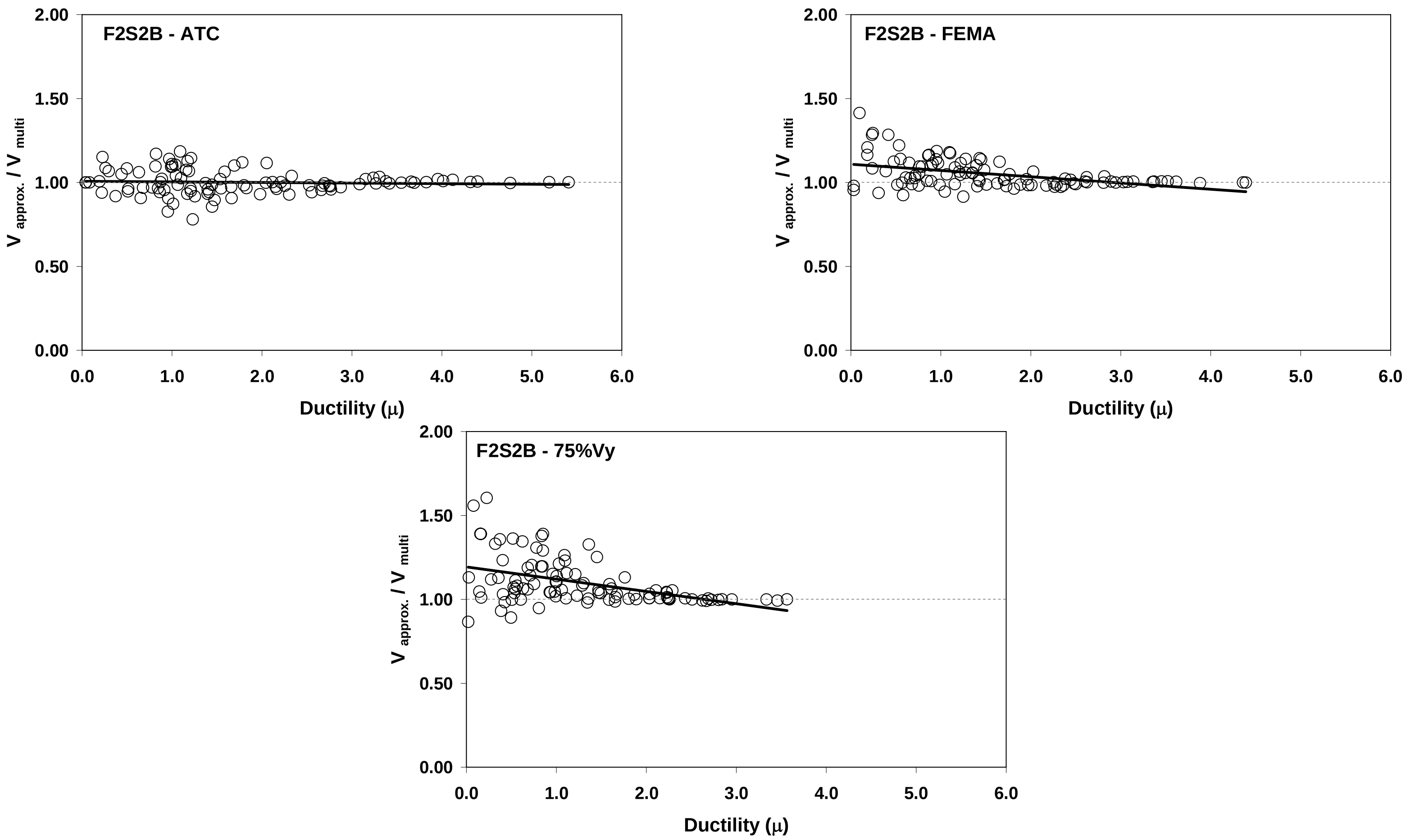


Figure A.7.71 Dependency on Ductility (Frame ‘F2S2B’ – Maximum Base Shear)

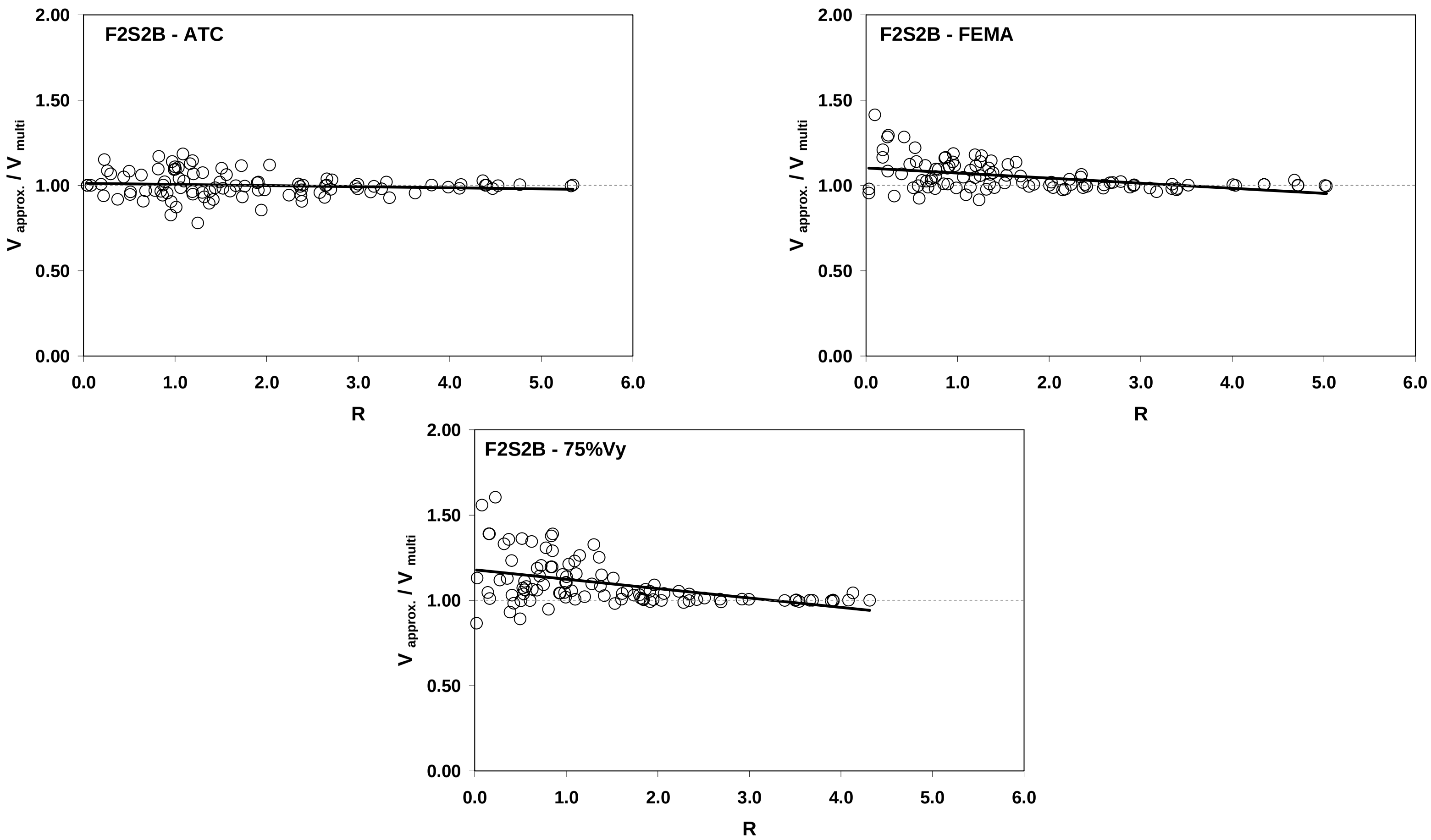


Figure A.7.72 Dependency on Strength Reduction Factor (Frame ‘F2S2B’ – Maximum Base Shear)

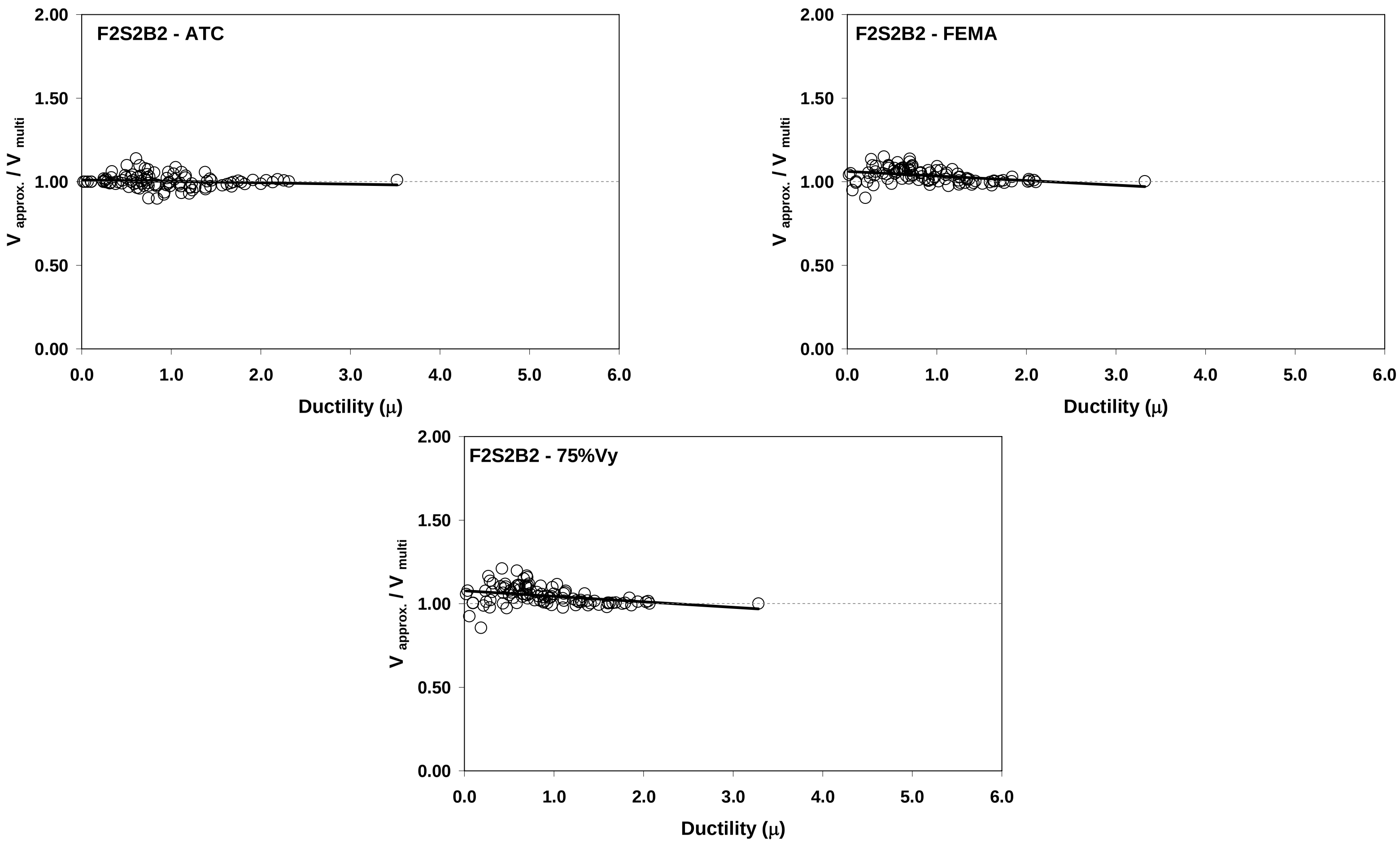


Figure A.7.73 Dependency on Ductility (Frame ‘F2S2B2’ – Maximum Base Shear)

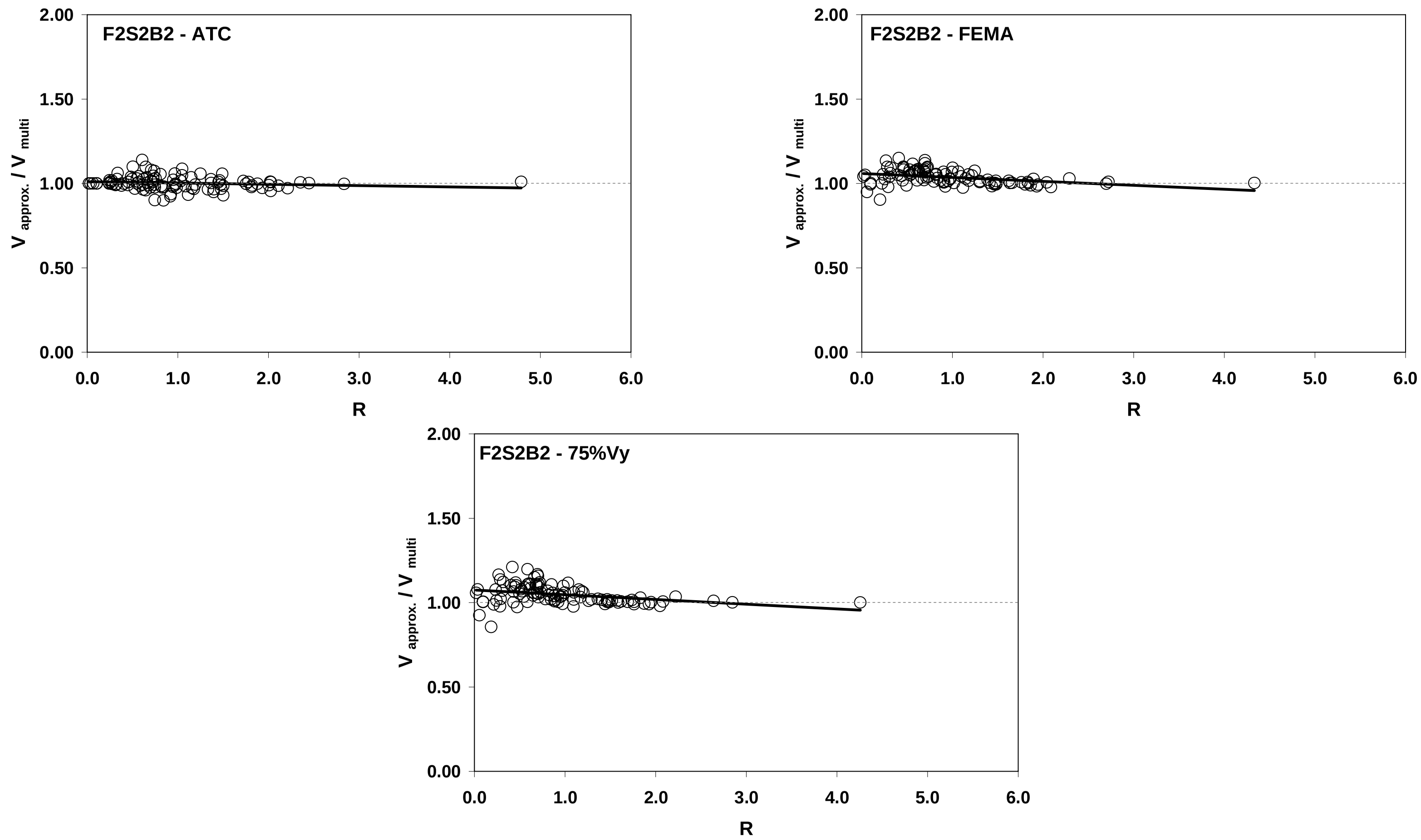


Figure A.7.74 Dependency on Strength Reduction Factor (Frame ‘F2S2B2’ – Maximum Base Shear)

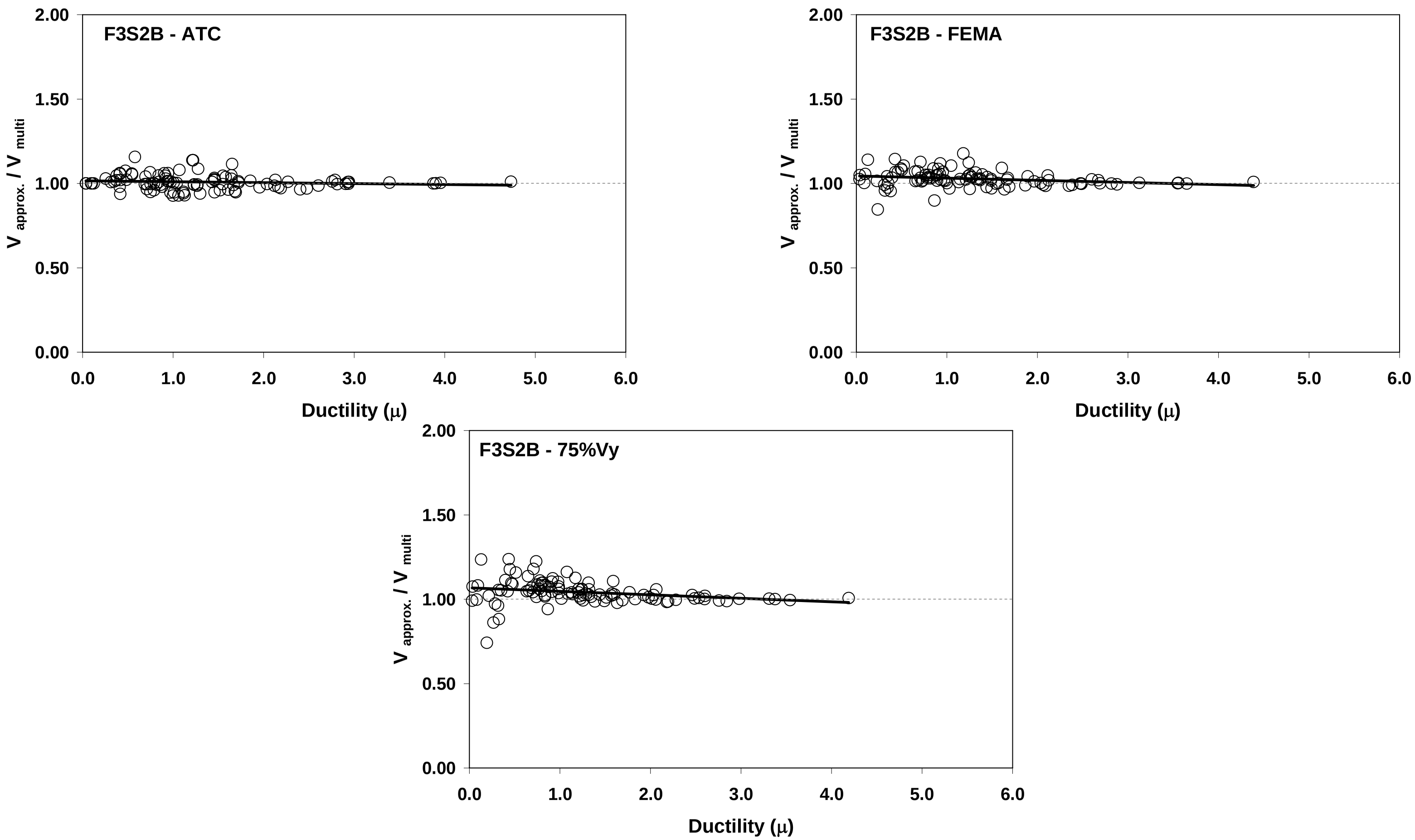


Figure A.7.75 Dependency on Ductility (Frame ‘F3S2B’ – Maximum Base Shear)

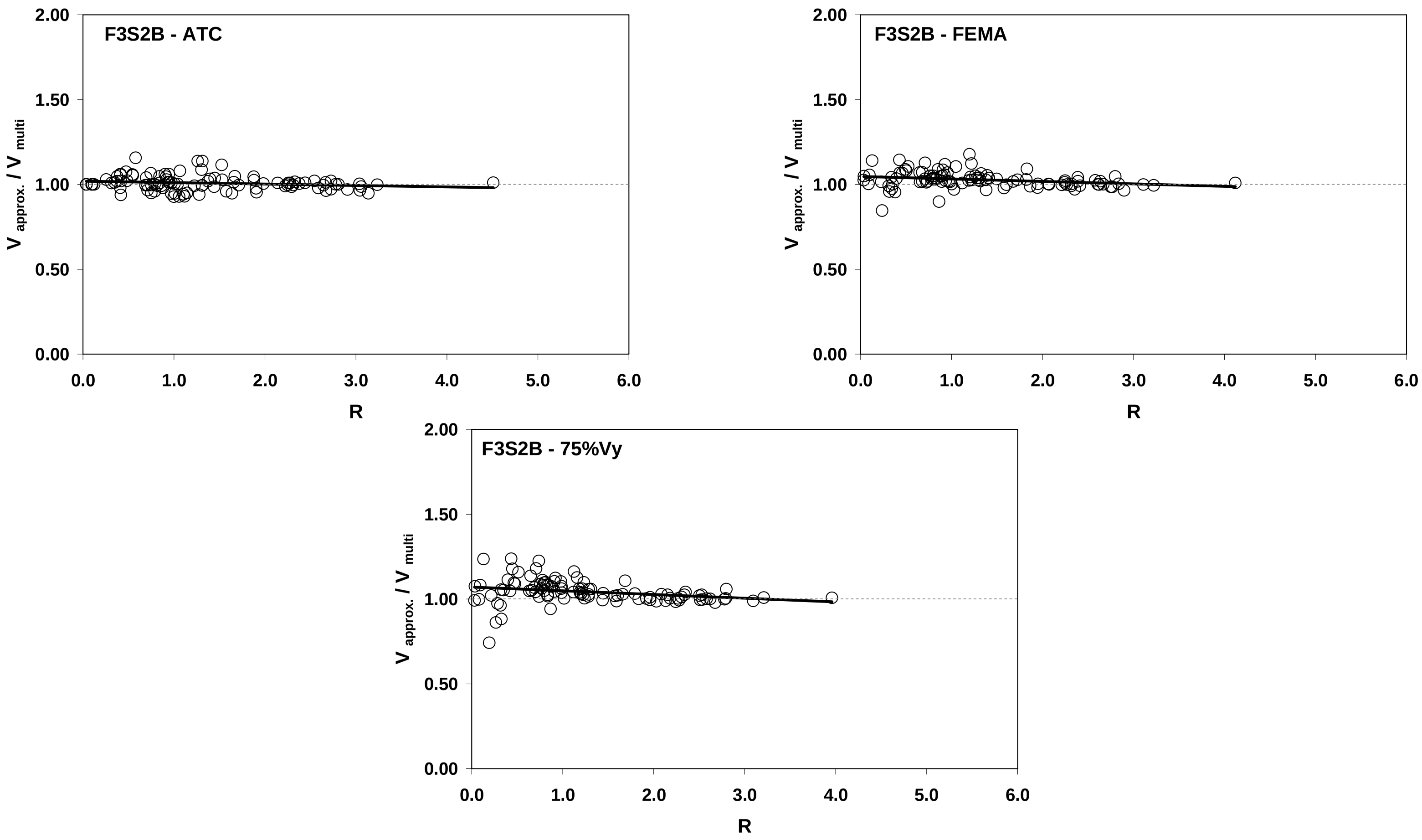


Figure A.7.76 Dependency on Strength Reduction Factor (Frame ‘F3S2B’ – Maximum Base Shear)

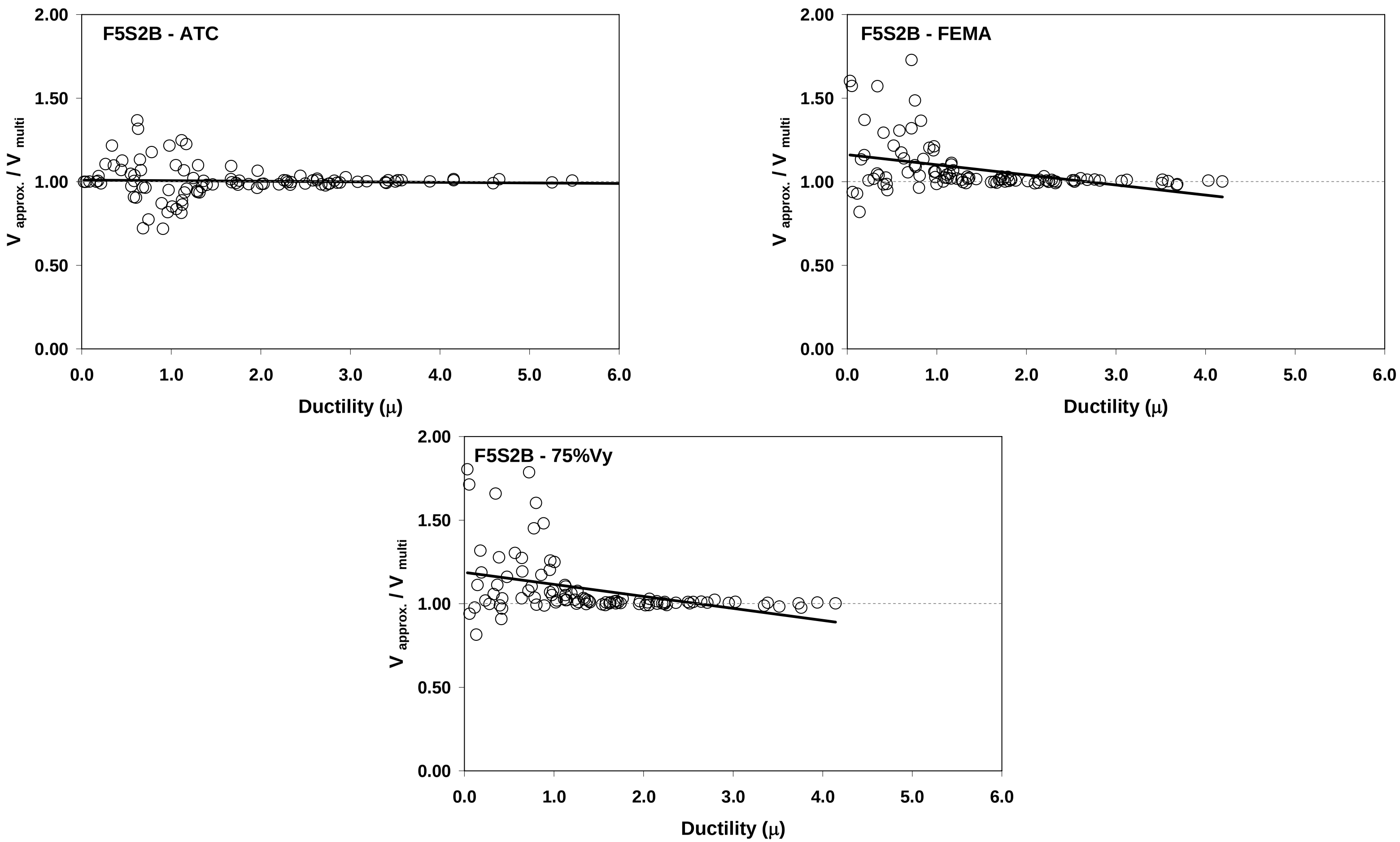


Figure A.7.77 Dependency on Ductility (Frame ‘F5S2B’ – Maximum Base Shear)

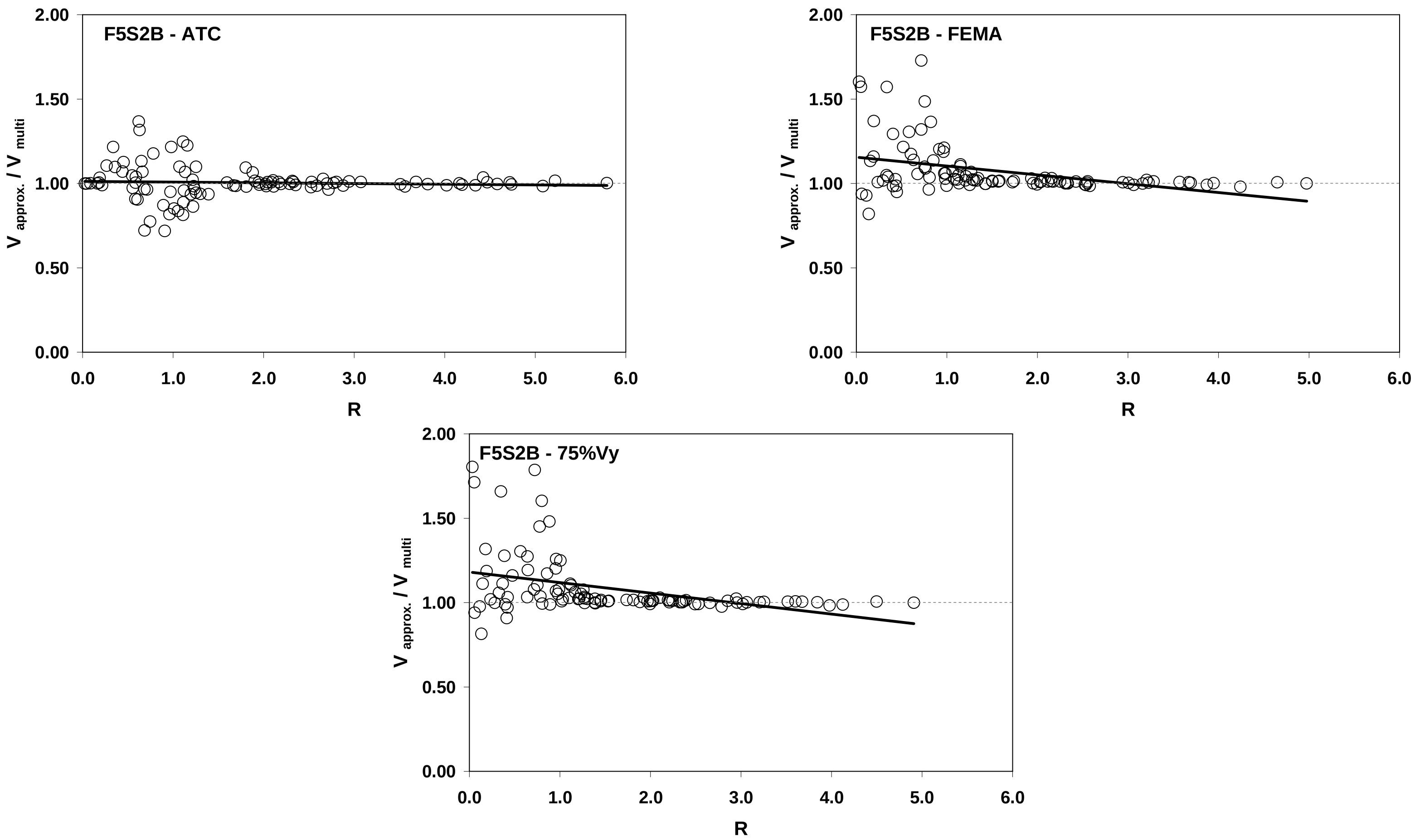


Figure A.7.78 Dependency on Strength Reduction Factor (Frame ‘F5S2B’ – Maximum Base Shear)

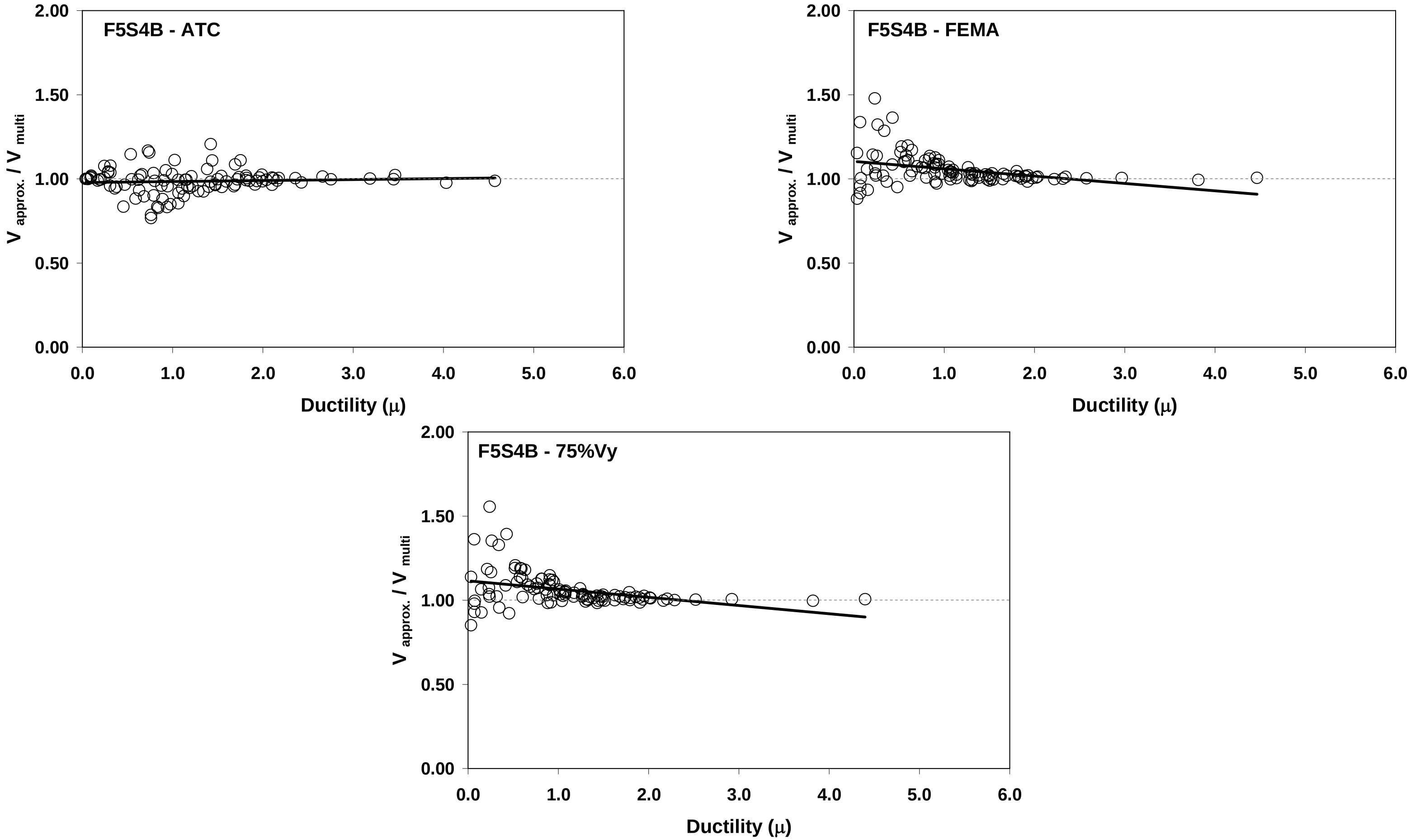


Figure A.7.79 Dependency on Ductility (Frame ‘F5S4B’ – Maximum Base Shear)

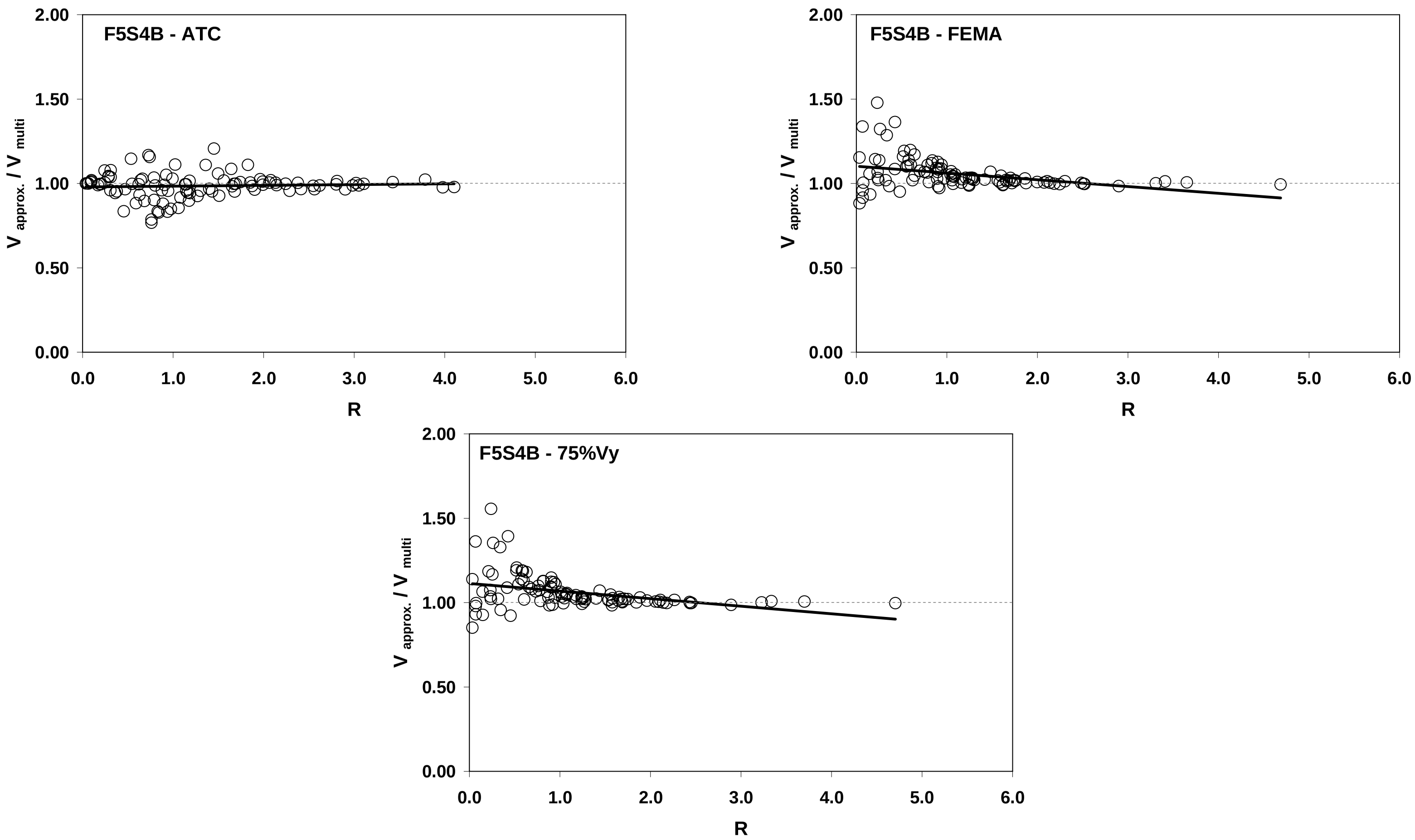


Figure A.7.80 Dependency on Strength Reduction Factor (Frame ‘F5S4B’ – Maximum Base Shear)

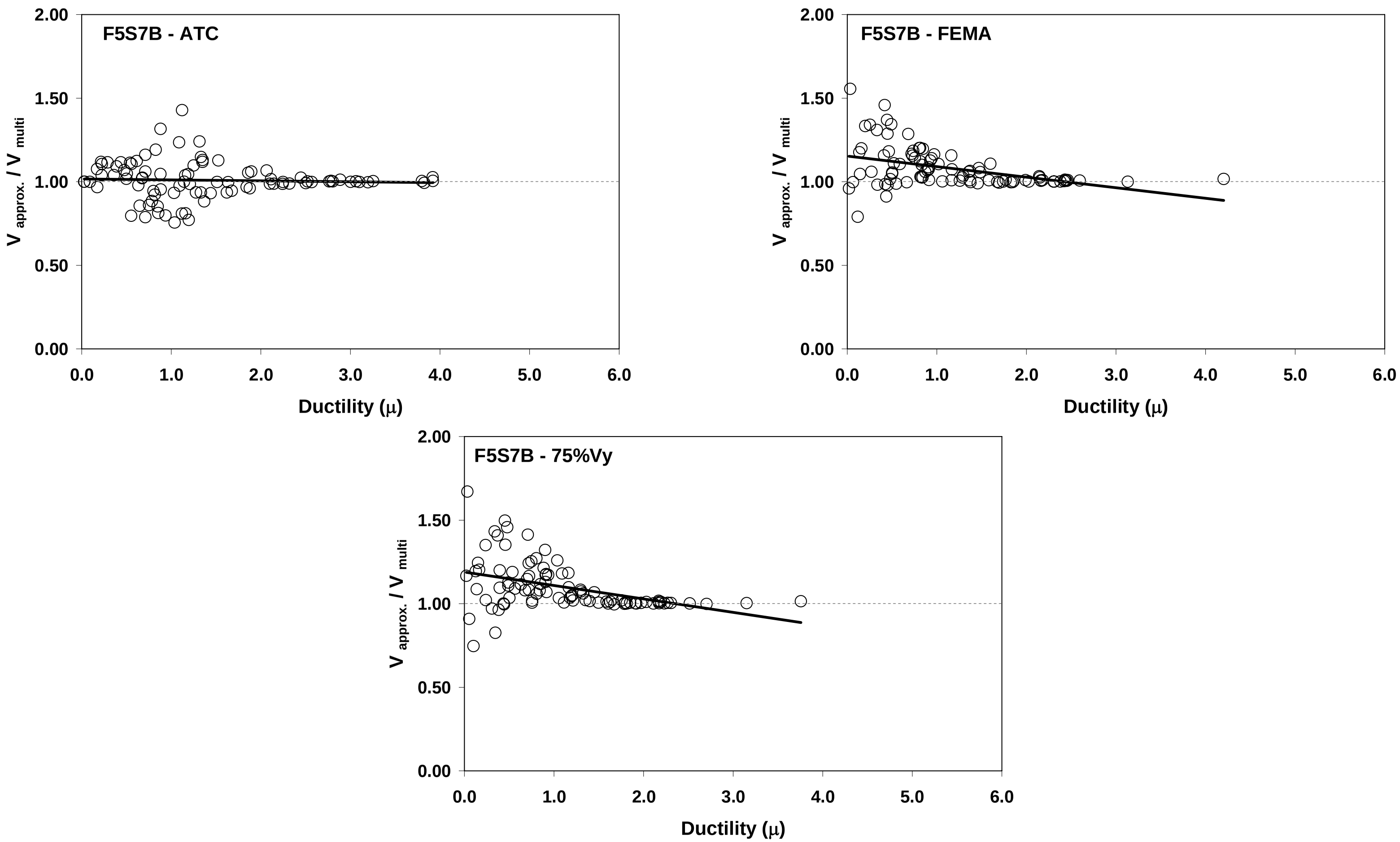


Figure A.7.81 Dependency on Ductility (Frame ‘F5S7B’ – Maximum Base Shear)

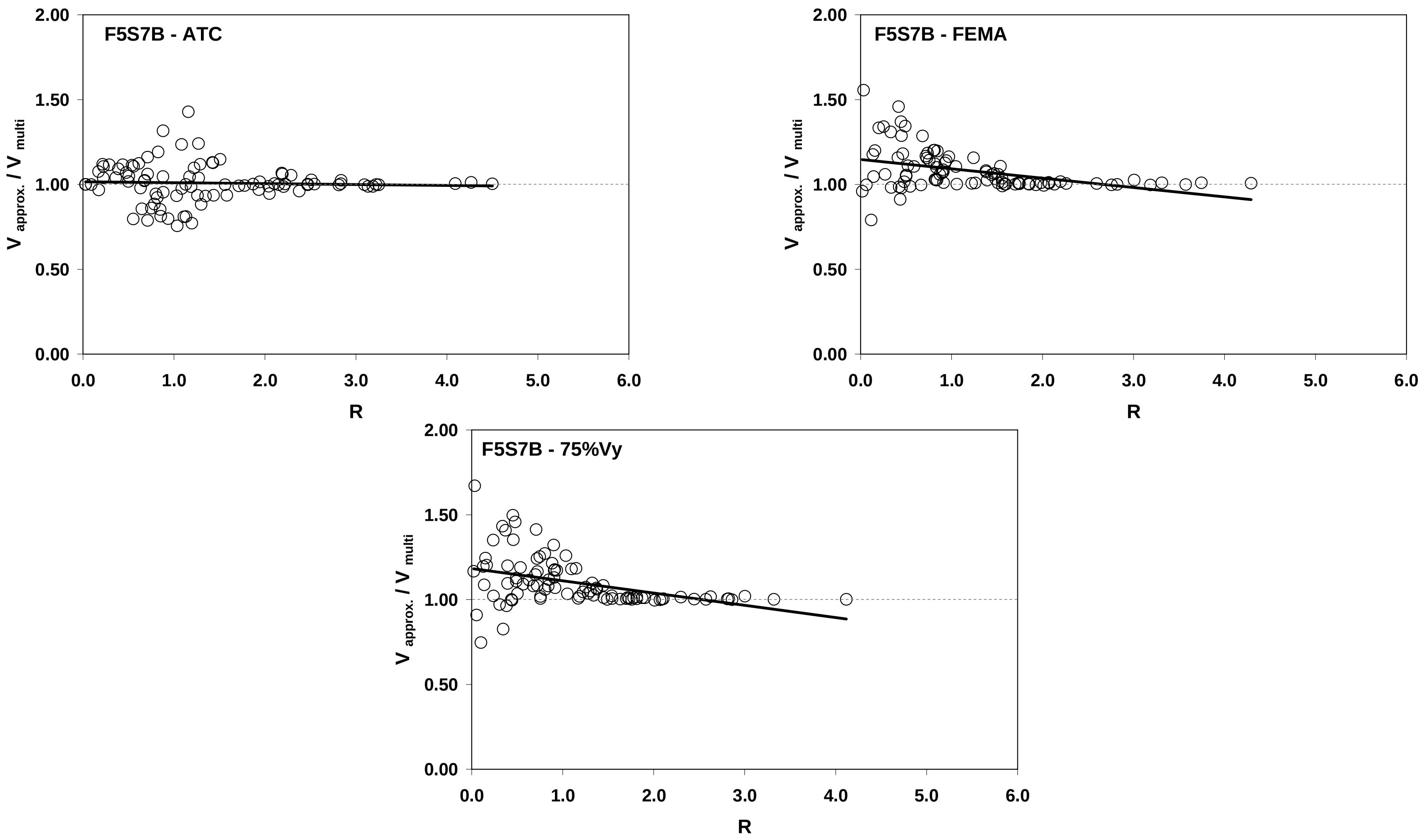


Figure A.7.82 Dependency on Strength Reduction Factor (Frame ‘F5S7B’ – Maximum Base Shear)

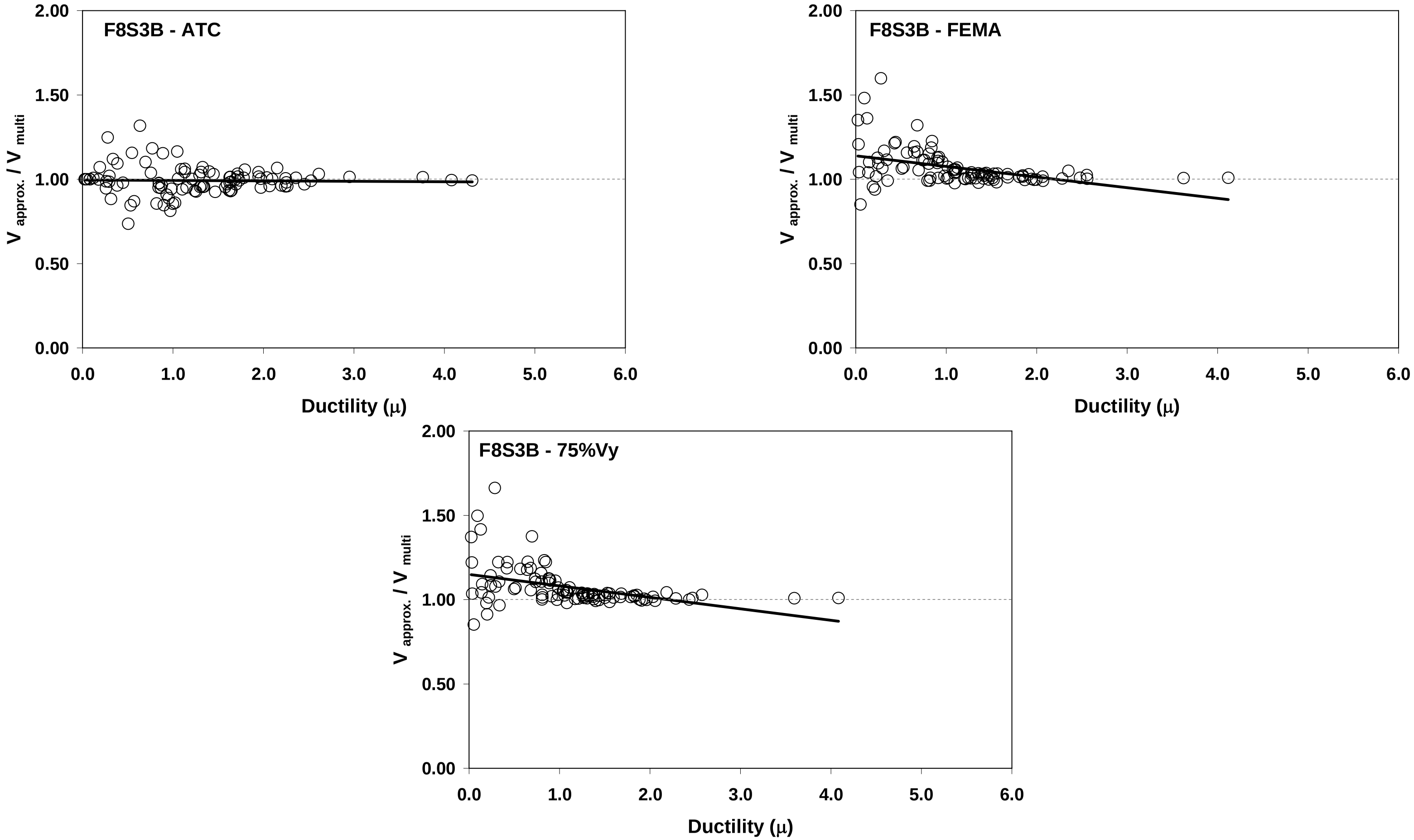


Figure A.7.83 Dependency on Ductility (Frame 'F8S3B' – Maximum Base Shear)

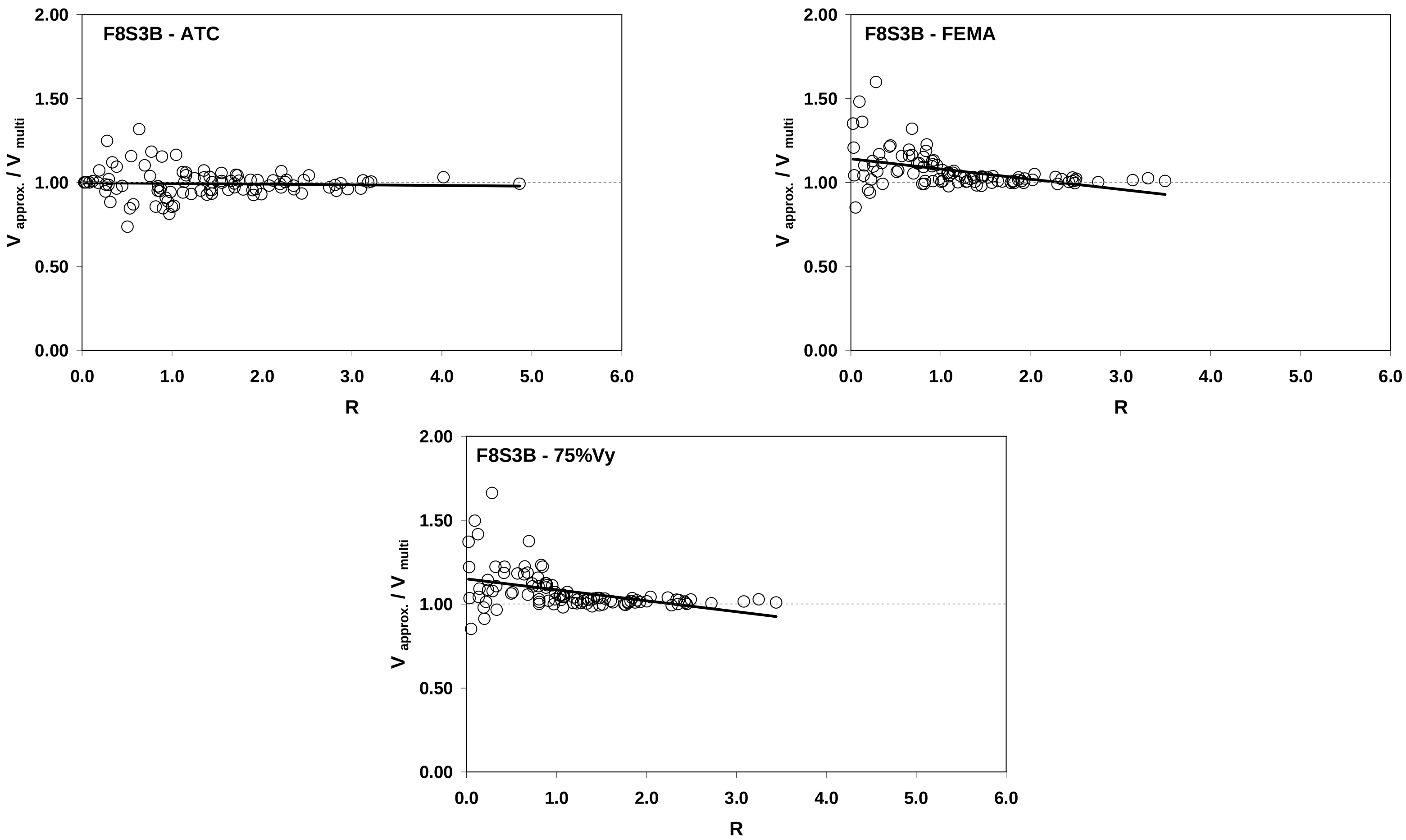


Figure A.7.84 Dependency on Strength Reduction Factor (Frame ‘F8S3B’ – Maximum Base Shear)

APPENDIX B

INTERPRETATION OF RESULTS WITH RESPECT TO

'MULTI' METHOD

B.1 INTRODUCTION

The interpretational steps presented in Chapter 4 were also repeated for the comparison of ATC, FEMA and 75%V_y approximations with respect to MULTI results. As previously indicated, this was done in order to investigate the performance of common approximation methods at capturing the global behavior (nonlinear static response) that was thought to be better presented by 'MULTI' approximation method which used the multi-linear segmented idealization to fully describe the capacity curve. The overall results are discussed in the next sections.

B.2 INTERPRETATIONS WITH RESPECT TO 'MULTI' RESULTS

B.2.1 Correlation Studies

Similar to the comparisons with 'exact' seismic responses, the demands obtained from the approximate procedures, ATC, FEMA and 75%V_y were compared with the ones obtained from MULTI method. 'Coefficient of correlation' for each comparison was also computed using Eqn. 4.1.

As depicted in Figure B.1 and Figures A.5.2-A.5.7, the maximum displacement demand comparisons indicated that all of the three methods gave identical results up to yielding of structural systems. After yield points, ATC method showed much dispersion with both under- and over-estimations. FEMA and 75%V_y methods, however, generally gave conservative results with respect to MULTI method. The correlation coefficient studies, as summarized in Table B.1, denoted that these two methods were strongly correlated with MULTI method, whereas ATC method gave relatively lower coefficient values indicating lower correlation.

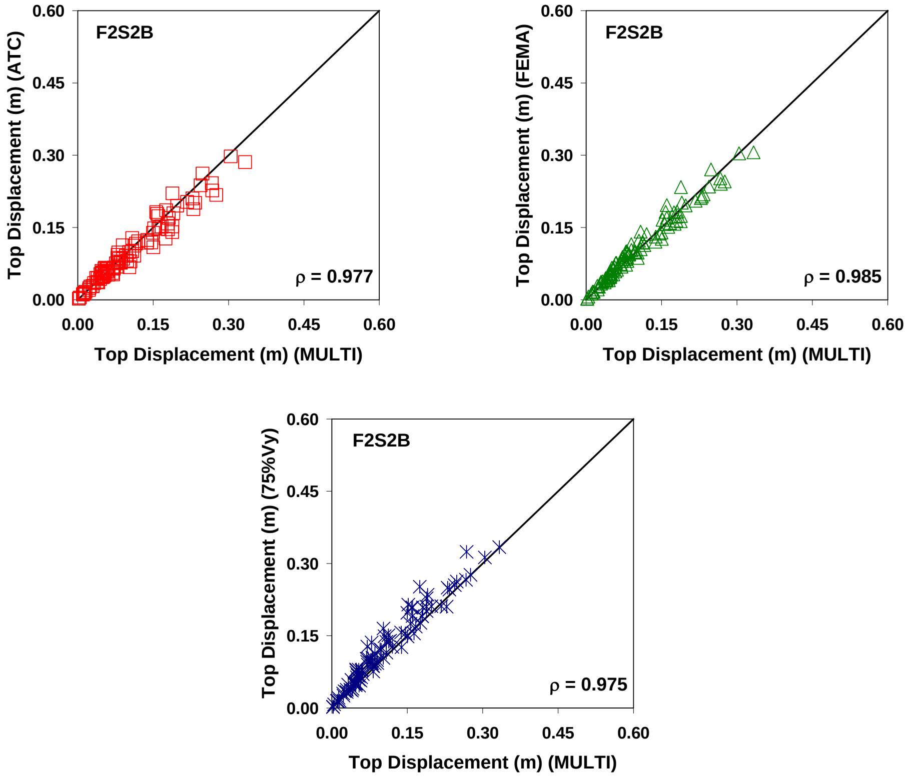


Figure B.1 Comparison of Approximate Results with respect to 'MULTI' Values of Maximum Top Displacement for Frame 'F2S2B'

Table B.1 Coefficient of Correlation Values of Approximation Alternatives at Predicting Maximum Top Displacement Demands

FRAME	ATC	FEMA	75%V_y
F2S2B	0.977	0.985	0.975
F2S2B2	0.992	0.994	0.994
F3S2B	0.991	0.992	0.991
F5S2B	0.969	0.975	0.976
F5S4B	0.971	0.993	0.993
F5S7B	0.905	0.980	0.984
F8S3B	0.965	0.989	0.990
Overall Mean	0.967	0.987	0.986

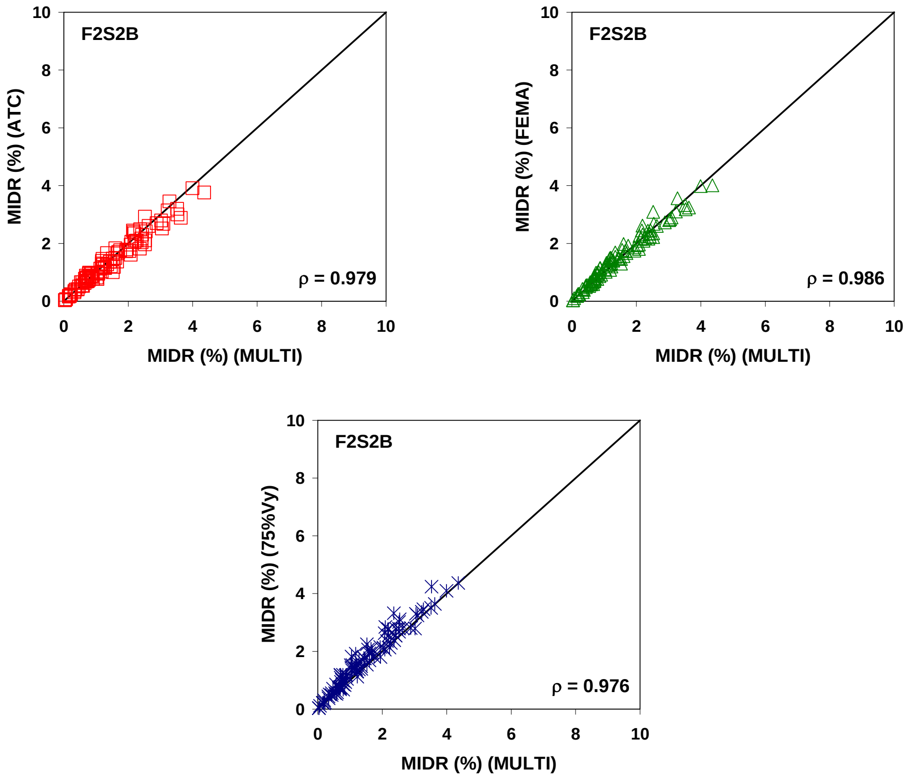


Figure B.2 Comparison of Approximate Results with respect to 'MULTI' Values of Maximum Inter-Story Drift Ratio for Frame 'F2S2B'

Table B.2 Coefficient of Correlation Values of Approximation Alternatives at Predicting Maximum Inter-Story Drift Ratio Demands

FRAME	**ATC**	**FEMA**	**75%V_y**
F2S2B	0.979	0.986	0.976
F2S2B2	0.992	0.995	0.994
F3S2B	0.991	0.992	0.991
F5S2B	0.968	0.972	0.974
F5S4B	0.972	0.993	0.993
F5S7B	0.903	0.980	0.984
F8S3B	0.962	0.989	0.990
Overall Mean	0.967	0.987	0.986

Considering the maximum inter-story drift ratio demand comparisons, as illustrated through Figure B.2 and Figures A.5.9-A.5.14, all of the methods matched very well with MULTI method except for few cases. In those cases, ATC method yielded scattered results also supported with the correlation studies whose outcomes are given in Table B.2. On the other hand, starting from moderate drift levels, FEMA and 75%V_y methods generally over-estimated the drift demands but exhibited strong correlation with the global behavior.

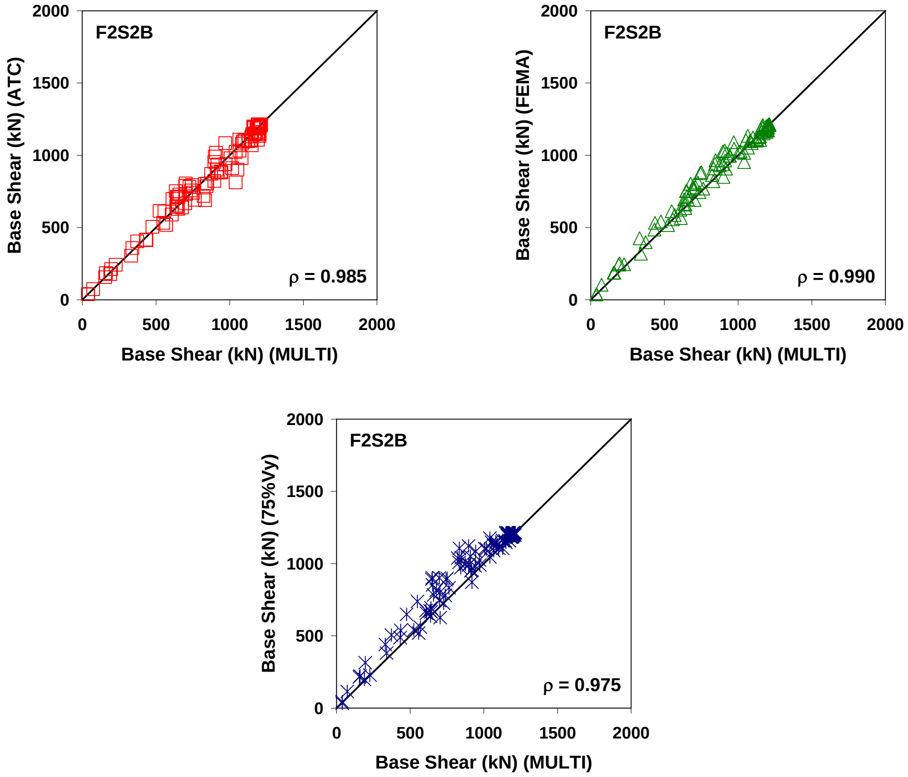


Figure B.3 Comparison of Approximate Results with respect to ‘MULTI’ Values of Maximum Base Shear for Frame ‘F2S2B’

Similarly, the comparisons regarding base shear demands are given in Figure B.3 and Figures A.5.16-A.5.21. According to these figures, all methods correlated well with MULTI method until yield strength regions. In the range of yield base shear values, the methods differentiated from global behavior. ATC method yielded varying results. Unlike ATC, FEMA and 75%V_y bi-linearization methods over-estimated base shear demands. However, a capacity curve dependent on elastic first mode lateral load pattern is just the lower bound for a structure. Thus, by yielding conservative results with respect to MULTI method, FEMA and 75%V_y methods was thought to approach the global behavior in a better sense. At high levels of shear force, methods again matched well with MULTI method. According to the statistical study results as given in Table B.3, the results of FEMA and 75%V_y methods were observed to correlate well with the ones of MULTI method. The coefficient of correlation for ATC method again remained lower as similar in other seismic response predictions.

Table B.3 Coefficient of Correlation Values of Approximation Alternatives at Predicting Maximum Base Shear Demands

FRAME	**ATC**	**FEMA**	**75%V_y**
F2S2B	0.985	0.990	0.975
F2S2B2	0.996	0.997	0.995
F3S2B	0.994	0.995	0.993
F5S2B	0.974	0.981	0.973
F5S4B	0.986	0.995	0.994
F5S7B	0.968	0.989	0.980
F8S3B	0.987	0.993	0.992
Overall Mean	0.984	0.991	0.986

B.2.2 Comparison of Methods at Various Levels of Global Drift

Statistical steps followed for the comparison of results with respect to 'exact' results were repeated for the comparison of the bi-linearization methods' results with respect to 'MULTI' results. Additionally, the lumped results were presented in a similar manner.

The gathered comparisons for maximum top displacement predictions, as given in Figure B.4 and Figures A.6.23-A.6.28, indicated that ATC method gave very close estimates in the error range of 10% with respect to 'MULTI' method. The other two methods generally over-estimated the results with mean errors as much as 25%. However, FEMA generally remained closer to the exact prediction line. Considering the general trend in mean errors and standard deviations at specified global drifts, ATC method matched up with 'MULTI' results in a better sense.

Similarly, the comparison graphs for maximum inter-story drift ratio results, as given in Figure B.5 and Figures A.6.30-A.6.35, revealed that the interpretations for critical drift demand estimations were same as the cases of maximum top displacement predictions. This situation can be explained by the fact that since critical drift demands were computed from the capacity curves at the target displacements, the errors in drift predictions would not be so different than the ones of displacement demands. Additionally, the almost unchanged elastic drift distribution of each frame at various global drift levels would have preserved the errors to remain in the same order.

The comparisons of base shear demands of approximations with respect to 'MULTI' predictions, as illustrated in Figure B.6 and Figures A.6.37-A.6.42, showed that ATC method predicted the force demand very closely surpassing the alternative methods at elastic regions. FEMA and 75%V_y, on the other hand, gave conservative results such as 15% over-estimations. Actually, FEMA was observed to estimate the force demand with respect to global behavior in a better sense. This general observation at elastic regions later turned to the case of similar and close predictions of approximation methods as expected from the bi-linear approximations of global behavior.

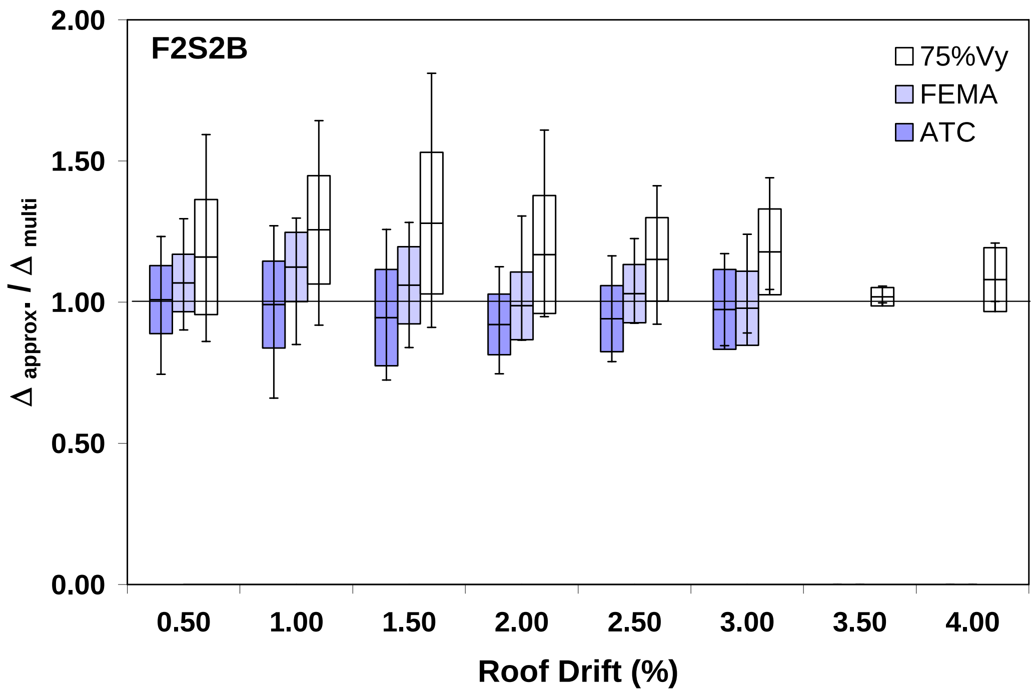


Figure B.4 Comparison of Approximations with respect to 'MULTI' Values of Maximum Top Displacement at Specified Global Roof Drifts for Frame 'F2S2B'

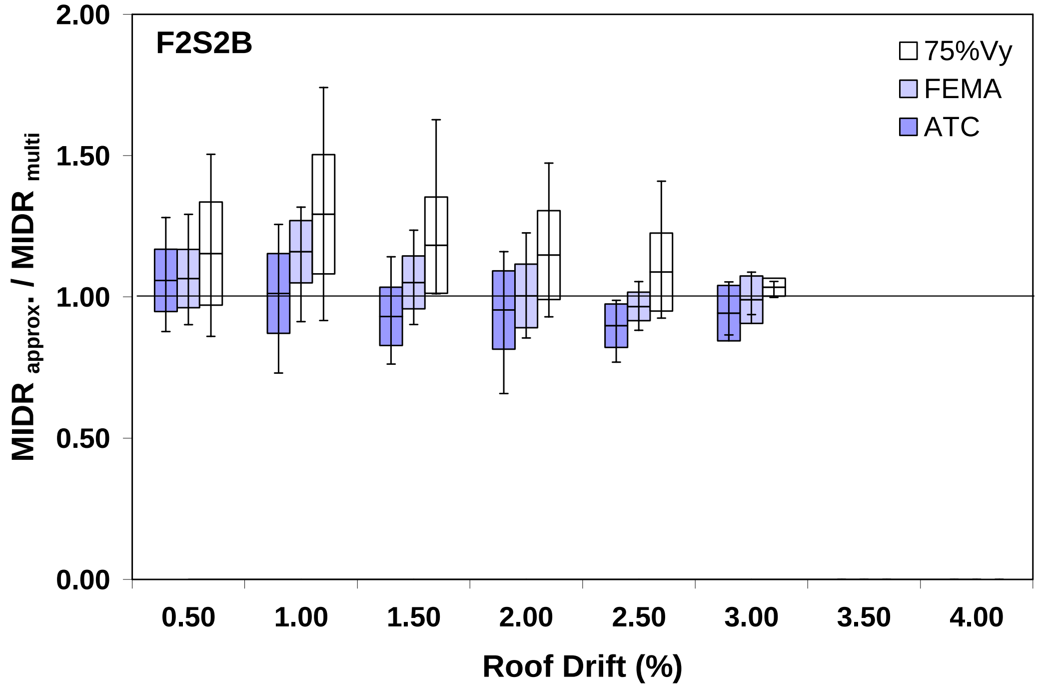


Figure B.5 Comparison of Approximations with respect to ‘MULTI’ Values of Maximum Inter-Story Drift Ratio at Specified Global Roof Drifts for Frame ‘F2S2B’

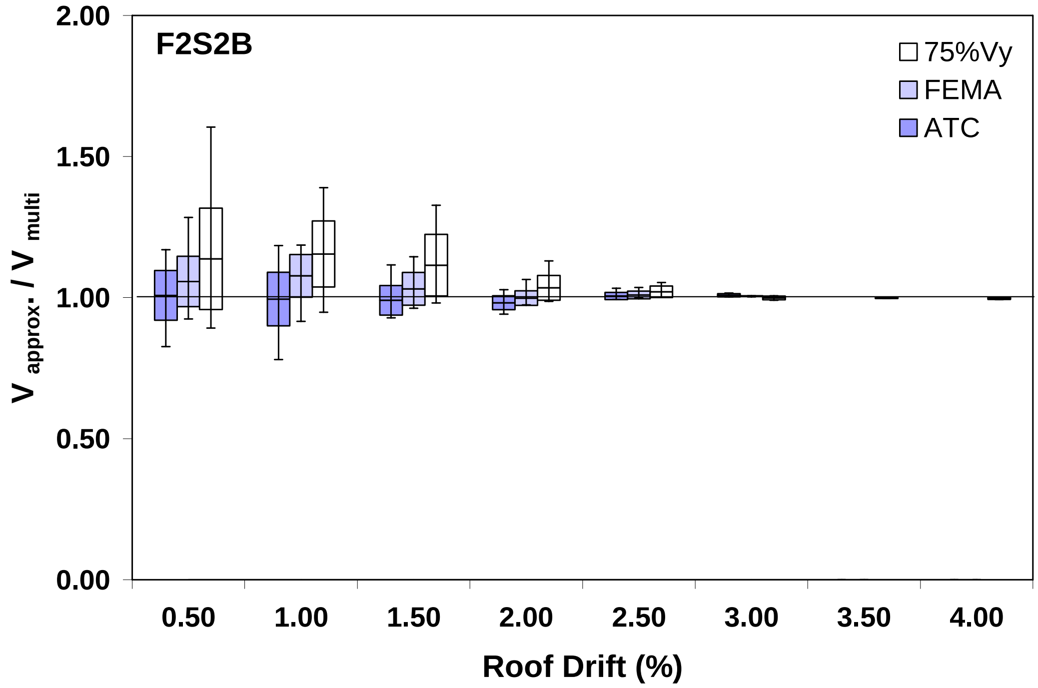


Figure B.6 Comparison of Approximations with respect to ‘MULTI’ Values of Maximum Base Shear at Specified Global Roof Drifts for Frame ‘F2S2B’

B.2.3 Period-wise Comparison of Methods

Period-wise comparison of approximation methods with respect to 'exact' results was also repeated to compare the results of bi-linear approximations with respect to 'MULTI' results for each frame. Figure B.7 showed that maximum top displacement demand predictions of ATC method, in average for each frame, were very close to 'MULTI' predictions indicating perfect match in comparison to other bi-linearization alternatives. In contrast, for all frames, FEMA and 75%V_y methods over-estimated with mean errors reaching almost 20%. Additionally, FEMA method yielded slightly lower over-estimations than 75%V_y as expected. Regarding the deviations in errors, all of the three methods gave similar values, but considering the minimum-maximum error couples, ATC method generally gave the lowest. Similar to the top displacement comparisons, as depicted in Figure B.8, it was observed in period-wise comparison of maximum drift ratio predictions that the error distribution remained almost same due to the previously expressed fact that the critical drift ratio was simply the drift ratio at the target displacement of the capacity curve, thus preserving the error of displacement predictions.

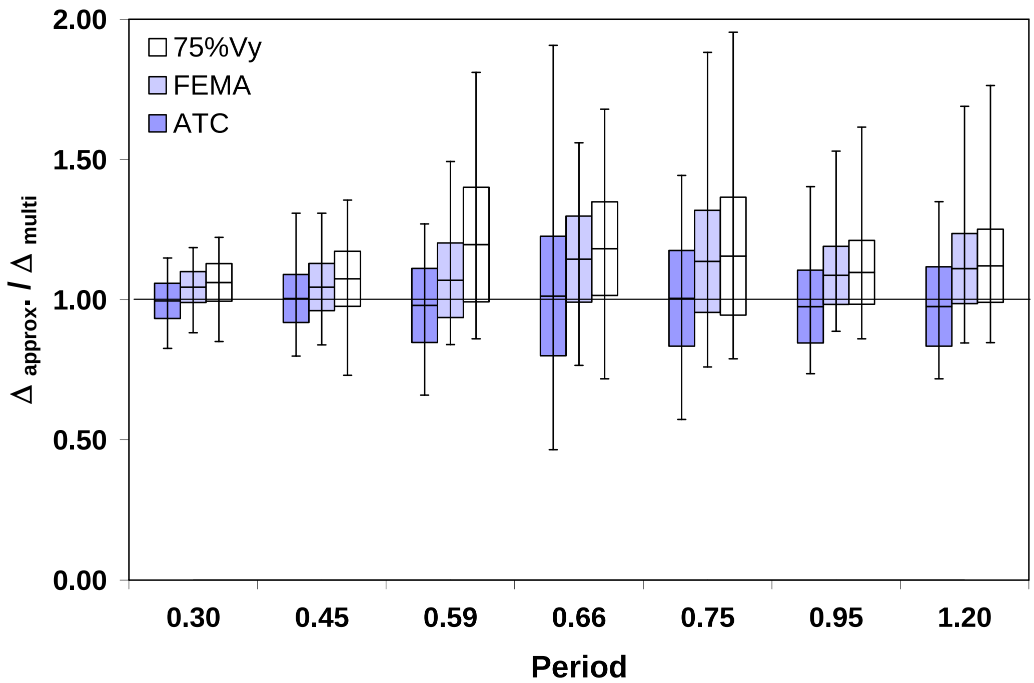


Figure B.7 Period-wise Distribution of Comparisons for
Maximum Displacement Demands with respect to 'MULTI' Results

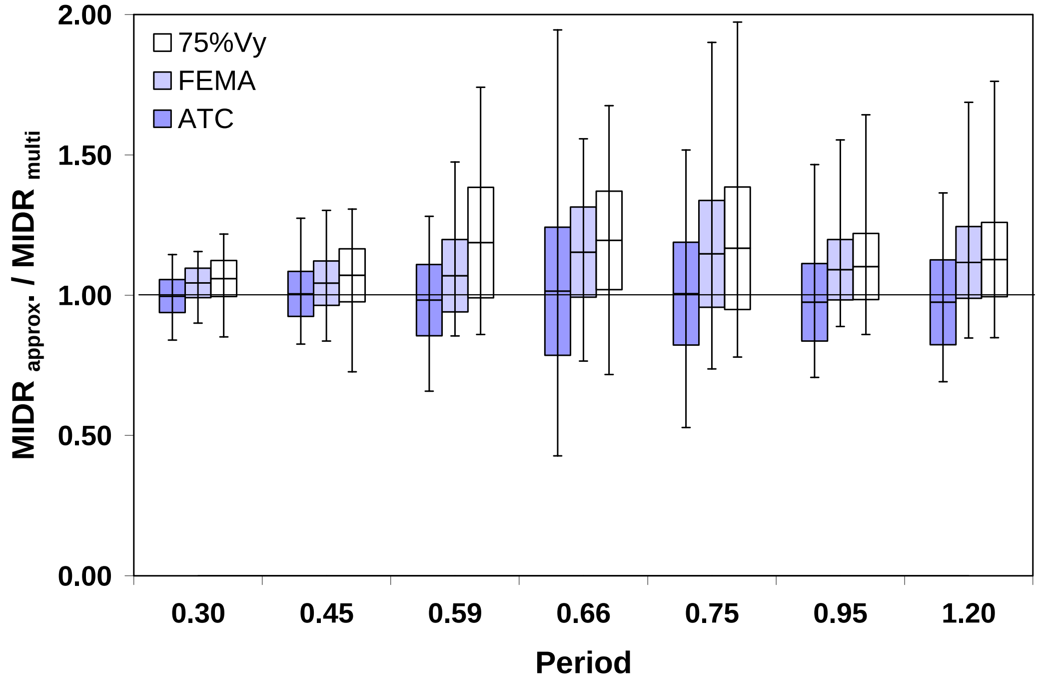


Figure B.8 Period-wise Distribution of Comparisons for
Maximum Inter-story Drift Ratio Demands with respect to 'MULTI' Results

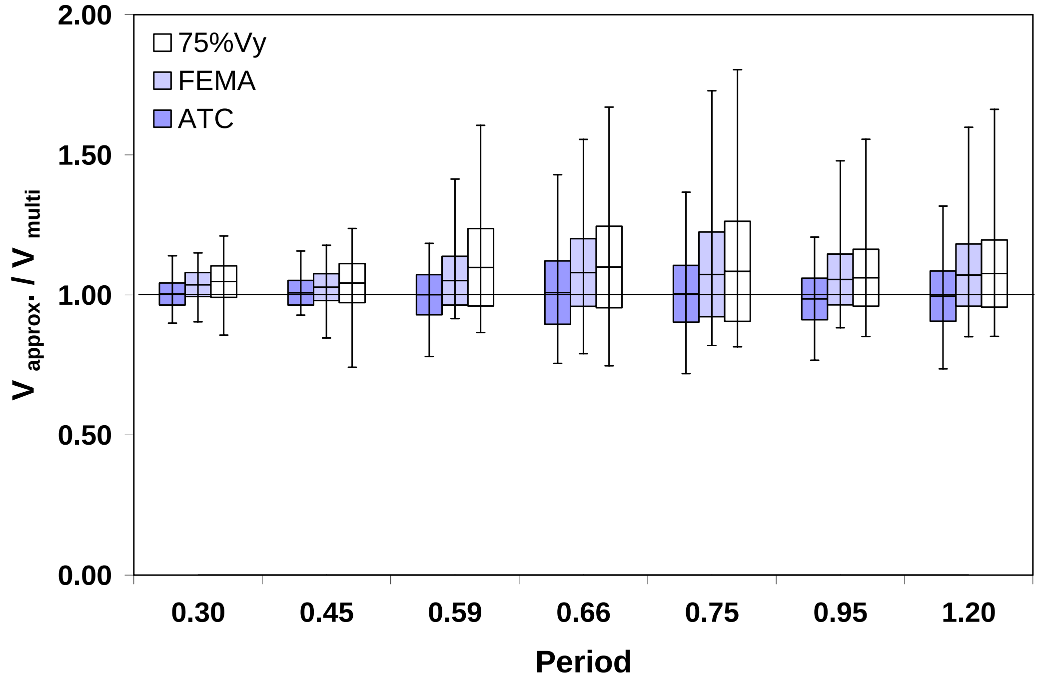


Figure B.9 Period-wise Distribution of Comparisons for
Maximum Base Shear Demands with respect to 'MULTI' Results

The comparisons concerning the mean errors for force demands with respect to each frame revealed that ATC method again matched very well with the results of 'MULTI' (Figure B.9). In addition, the deviation of the results of ATC method remained the lowest at all times. FEMA and 75%V_y, in contrast, gave conservative results with respect to elastic first mode lateral load pattern dependent global behavior as much as 10%. Furthermore, the standard deviations for these methods were turned out to be slightly larger than ATC.

The period-wise dependency graphs, as illustrated in Figures B.10-B.12, depicted that there was no obvious trend in the mean errors with increasing period. However, they reinforced the previous findings that ATC matched up with 'MULTI' results very well and this situation did not change with period change. In addition, FEMA and 75%V_y generally over-estimated the displacement and drift demands and this over-estimation tended to increase slightly with increasing period. In contrast, for force demands, the over-estimations were smaller and un-changed for all frame cases.

B.2.4 Trends and Dependencies on Ductility and Strength Reduction Factor

The steps in section 4.2.4 to investigate the dependencies with respect to 'exact' results were repeated for the investigation of the dependencies with respect to 'MULTI' values. Figures B-13-B.18 and Figures A.7.43-A.7.84 supported the earlier interpretations that ATC gave very close estimates with respect to global behavior in terms of displacement, drift and force demands. According to the dependency graphs for maximum top displacement and maximum inter-story drift ratio demand predictions, FEMA and 75%V_y started with over-estimations and these over-estimations generally showed a tendency to decrease with increasing ductility level and strength reduction factor.

In the case of maximum base shear force estimations; although the general trend of FEMA and 75%V_y methods seemed to decrease with increasing levels of inelasticity, this tendency was due to the low performance of the two methods at capturing global force demands in the elastic range. As previously discussed, after the yield of the systems, the approximation alternatives; ATC, FEMA and 75%V_y captured the global behavior very well in terms of maximum base shear demands. Thus, discarding the low performance of the methods in the elastic region, the tendency of error indicating ratios was not to change with the change of ductility level and strength reduction factor.

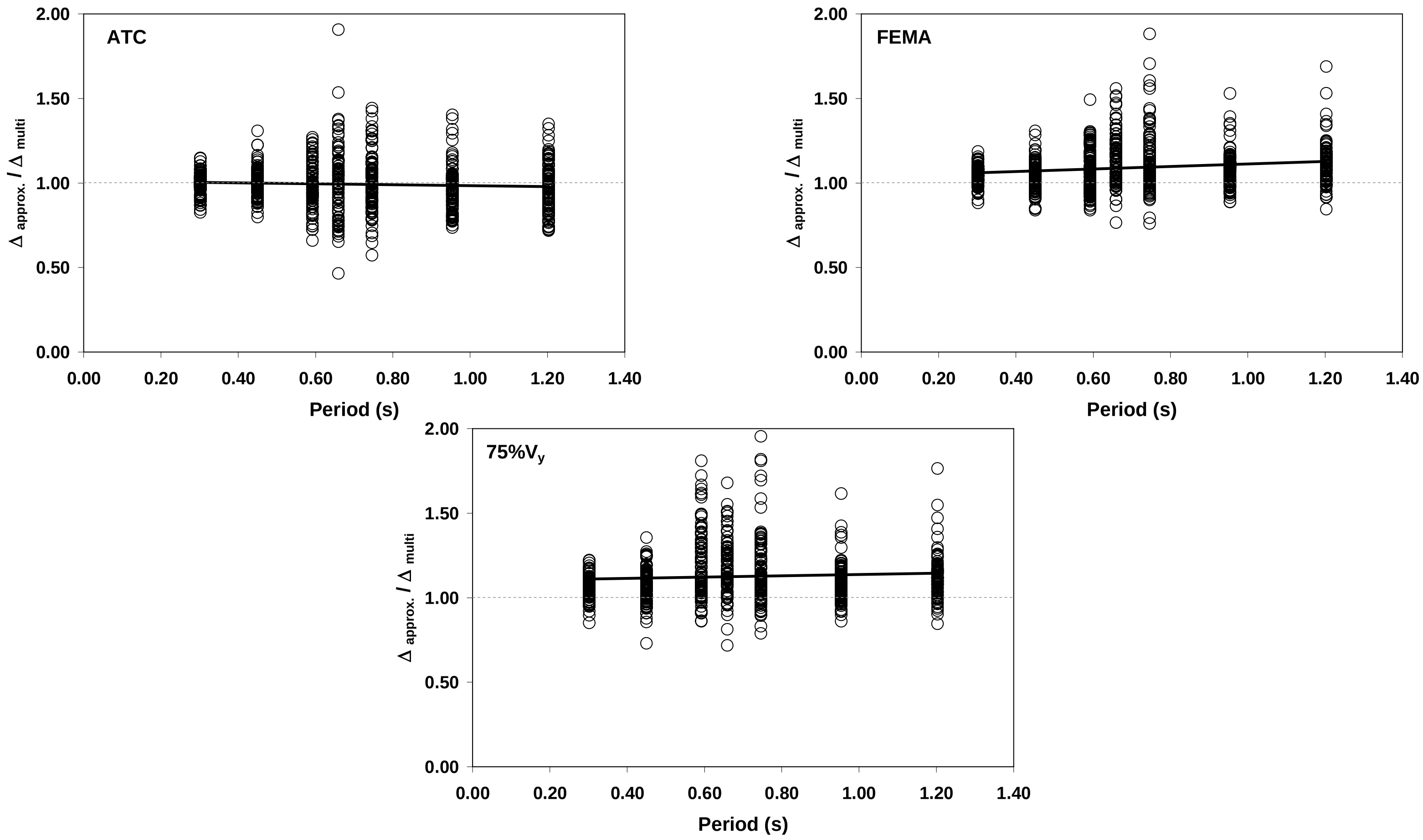


Figure B.10 Dependency on Period (Maximum Top Displacement)

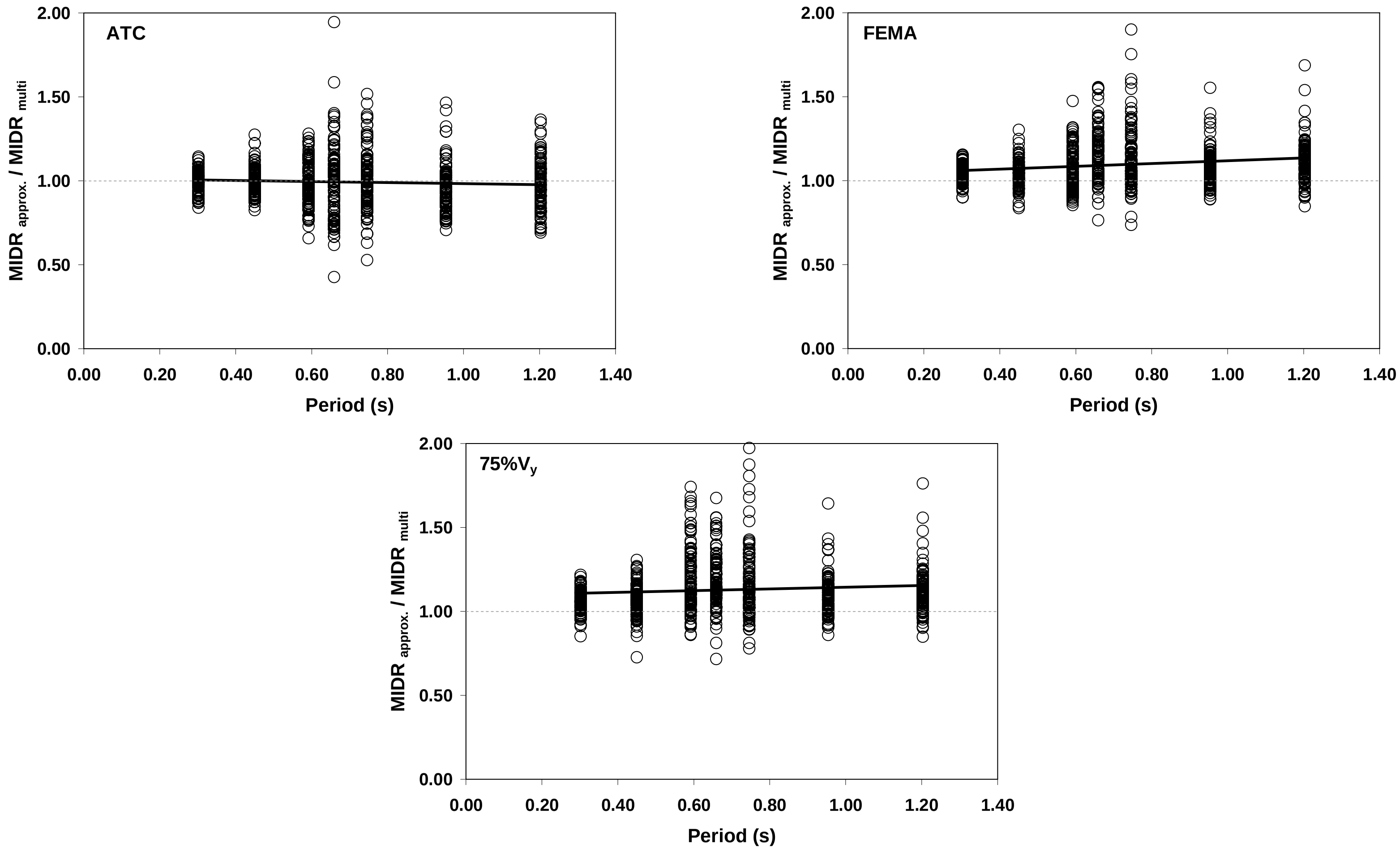


Figure B.11 Dependency on Period (Maximum Inter-Story Drift Ratio)

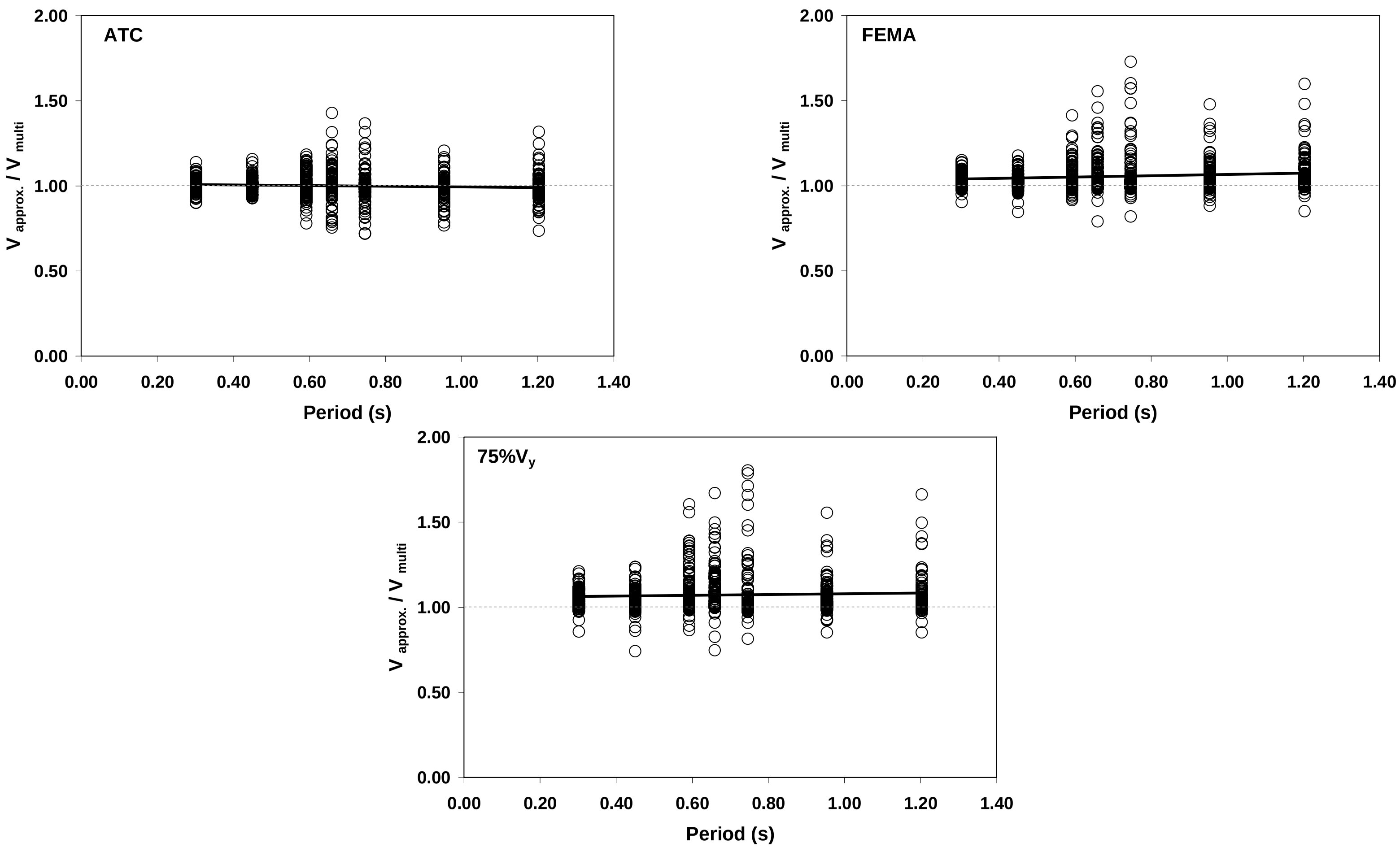


Figure B.12 Dependency on Period (Maximum Base Shear)

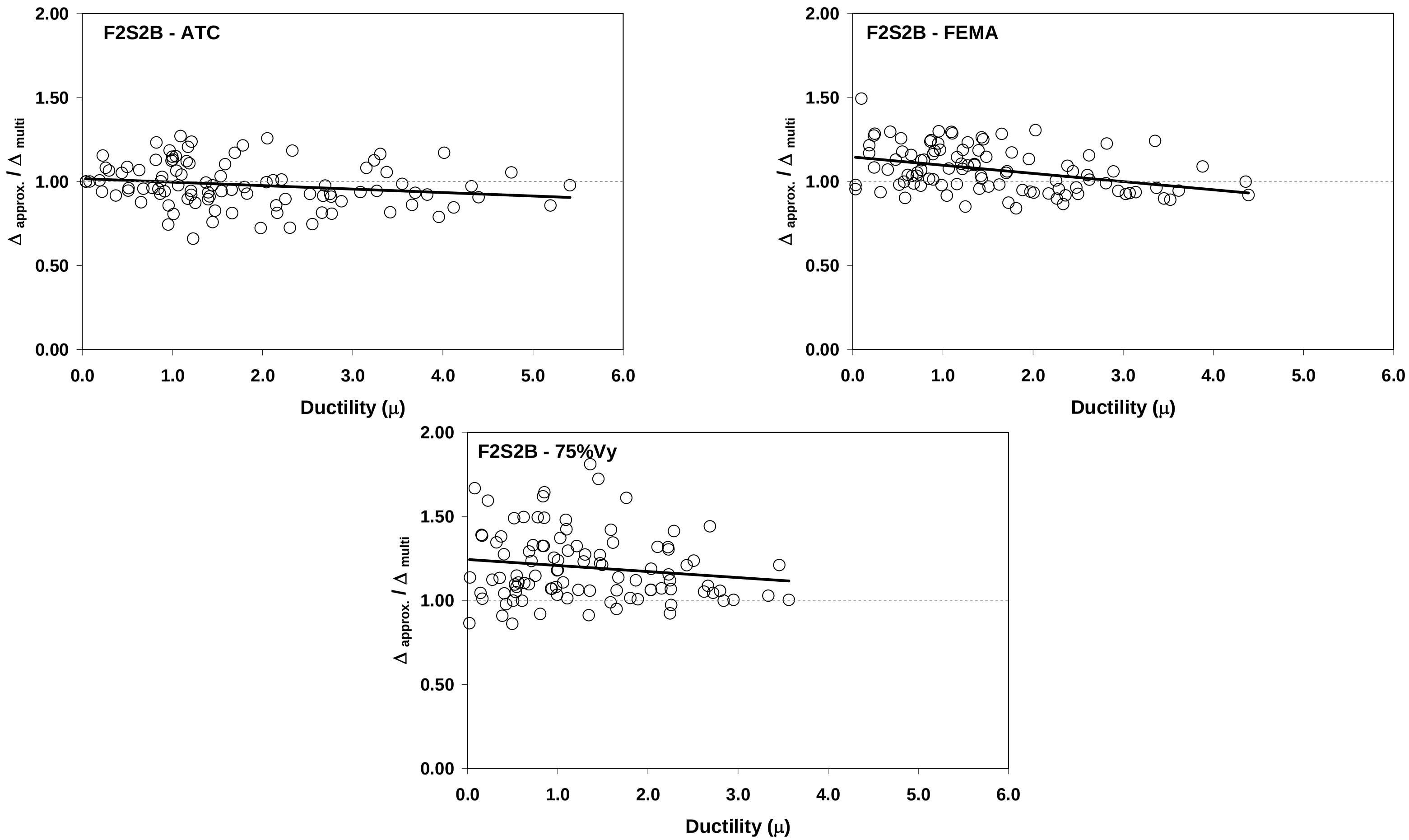


Figure B.13 Dependency on Ductility (Frame ‘F2S2B’ – Maximum Top Displacement)

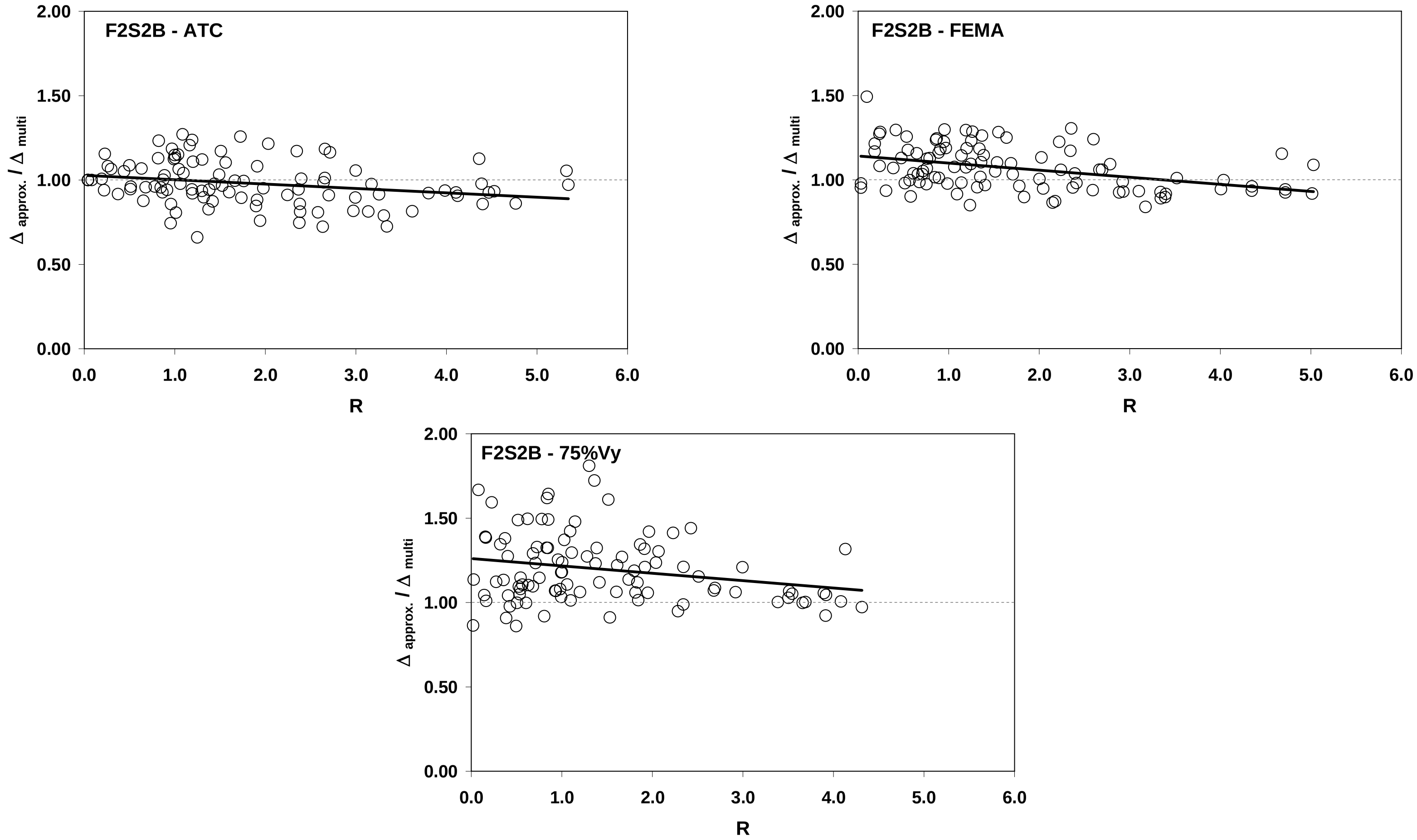


Figure B.14 Dependency on Strength Reduction Factor (Frame ‘F2S2B’ – Maximum Top Displacement)

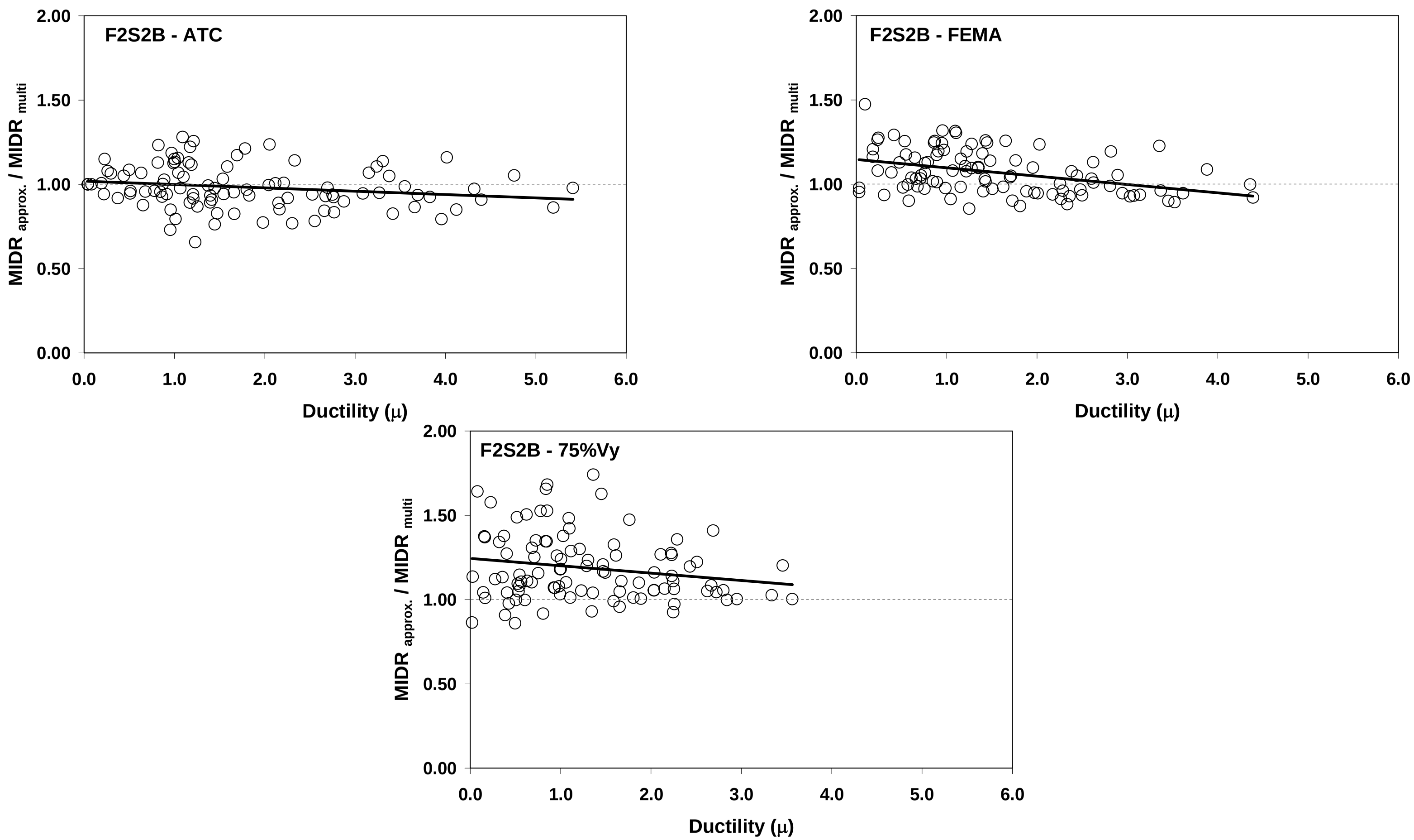


Figure B.15 Dependency on Ductility (Frame ‘F2S2B’ – Maximum Inter-Story Drift Ratio)

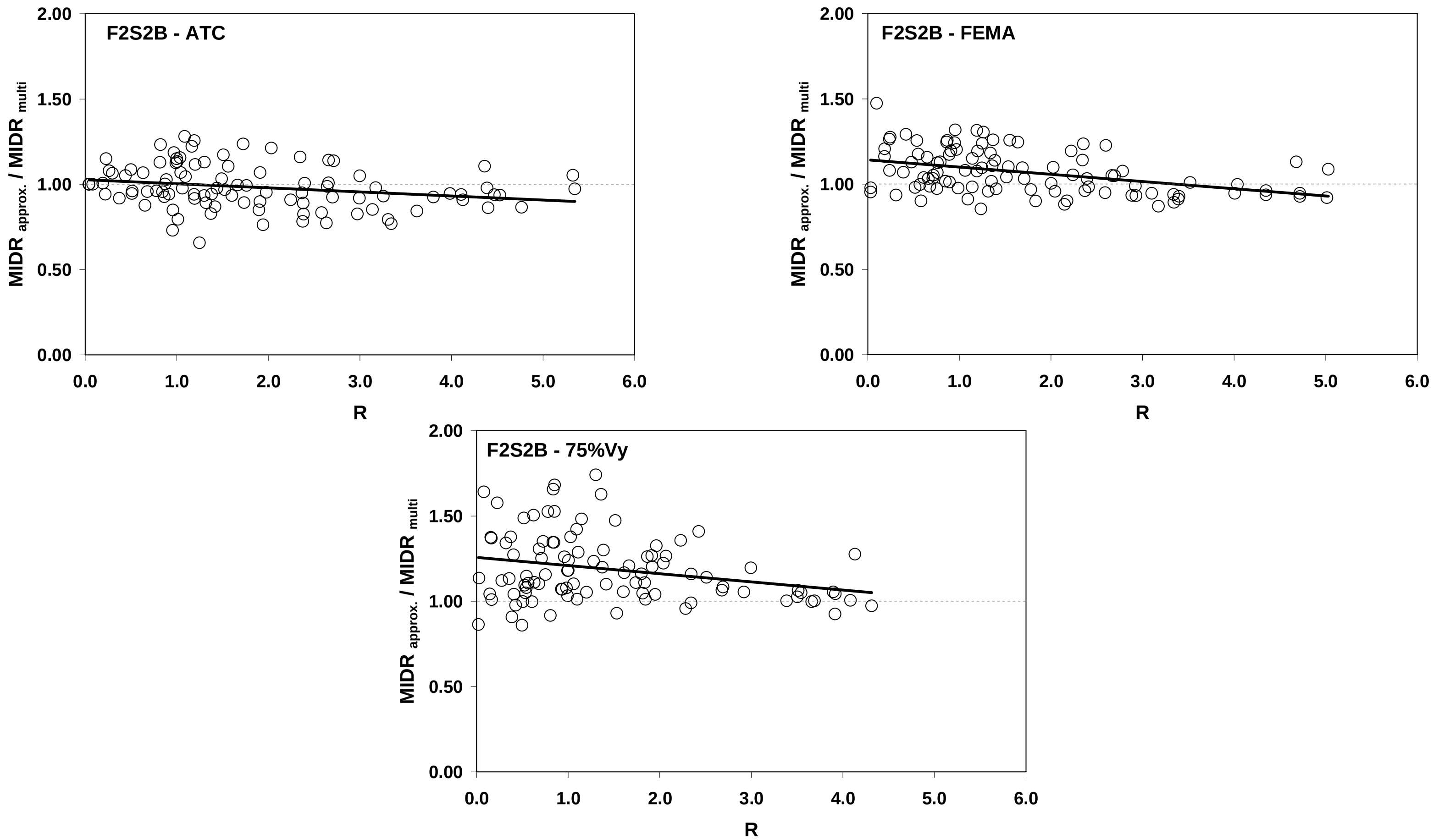


Figure B.16 Dependency on Strength Reduction Factor (Frame ‘F2S2B’ – Maximum Inter-Story Drift Ratio)

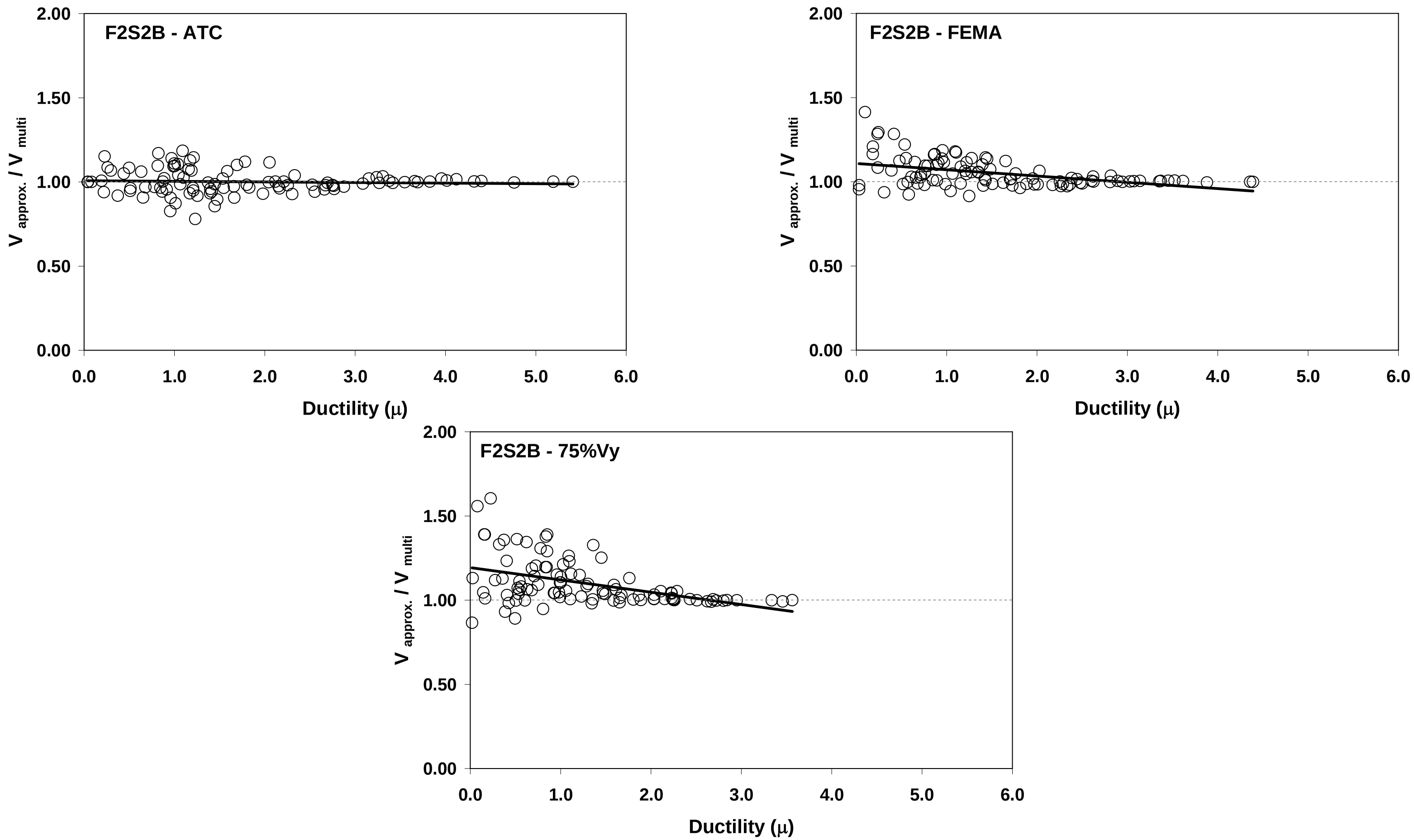


Figure B.17 Dependency on Ductility (Frame ‘F2S2B’ – Maximum Base Shear)

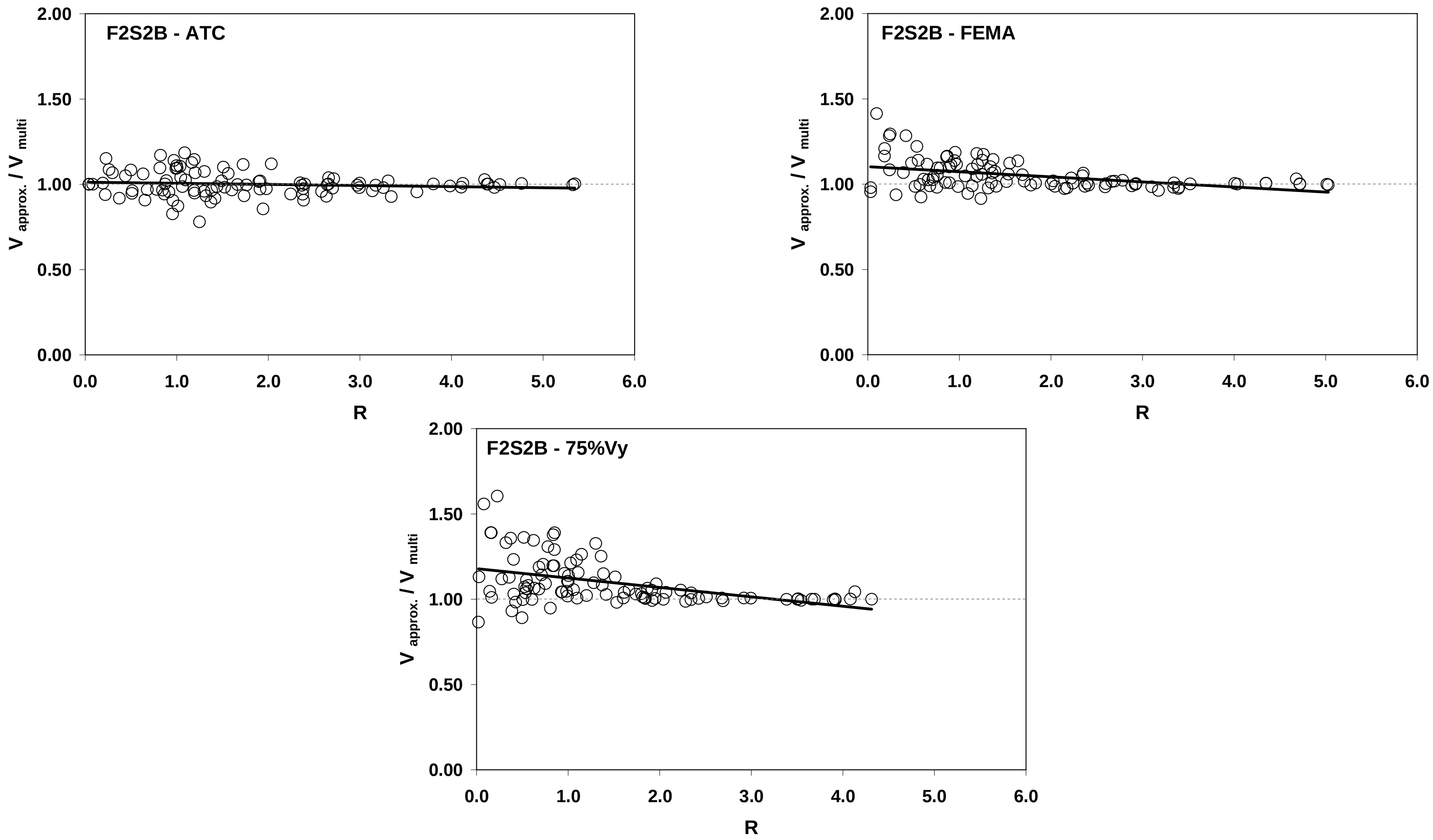


Figure B.18 Dependency on Strength Reduction Factor (Frame ‘F2S2B’ – Maximum Base Shear)

B.3 SUMMARY OF COMPARISONS

The comparison of the demand parameters computed from the approximations ATC, FEMA and 75%V_y with the results of MULTI method were presented in previous sections. The comparisons made at different drift, ductility and strength reduction values showed that ATC method captured the global behavior that was represented by MULTI method in a better sense with mean errors in the order of 10%. The predictions of ATC method were even better at elastic range due to the fact that both MULTI and ATC methods use same initial stiffness. Considering the summarized results given in Tables B.4-B-6, FEMA and 75%V_y methods over-estimated the displacement and maximum drift demands within 20 percent with the latter one being more conservative and the over-estimations were observed to decrease with increasing degrees of inelasticity. The uncertainty in the predictions was turned out to be in the same order.

Table B.4 Error Statistics for Maximum Top Displacement Estimations

FRAME	ATC		FEMA		75%V_y	
	Mean	**σ**	**Mean**	**σ**	**Mean**	**σ**
F2S2B	0.979	0.132	1.069	0.133	1.196	0.204
F2S2B2	0.996	0.063	1.045	0.055	1.061	0.067
F3S2B	1.004	0.086	1.045	0.084	1.074	0.098
F5S2B	1.005	0.170	1.137	0.182	1.155	0.210
F5S4B	0.975	0.130	1.087	0.104	1.097	0.114
F5S7B	1.013	0.213	1.144	0.154	1.182	0.167
F8S3B	0.976	0.142	1.111	0.125	1.121	0.130

Table B.5 Error Statistics for Maximum Inter-Story Drift Ratio Estimations

FRAME	ATC		FEMA		75%V_y	
	Mean	**σ**	**Mean**	**σ**	**Mean**	**σ**
F2S2B	0.982	0.127	1.069	0.129	1.187	0.197
F2S2B2	0.996	0.059	1.044	0.053	1.059	0.064
F3S2B	1.005	0.080	1.043	0.079	1.071	0.094
F5S2B	1.005	0.183	1.147	0.190	1.167	0.218
F5S4B	0.975	0.138	1.091	0.108	1.102	0.118
F5S7B	1.014	0.228	1.154	0.161	1.195	0.176
F8S3B	0.975	0.151	1.116	0.128	1.127	0.132

Table B.6 Error Statistics for Maximum Base Shear Estimations

FRAME	ATC		FEMA		75%V_y	
	Mean	**σ**	**Mean**	**σ**	**Mean**	**σ**
F2S2B	1.001	0.072	1.051	0.087	1.098	0.138
F2S2B2	1.003	0.039	1.036	0.043	1.047	0.056
F3S2B	1.008	0.044	1.028	0.048	1.042	0.070
F5S2B	1.004	0.101	1.073	0.151	1.084	0.179
F5S4B	0.985	0.074	1.055	0.091	1.061	0.101
F5S7B	1.009	0.113	1.080	0.121	1.100	0.146
F8S3B	0.996	0.090	1.071	0.111	1.076	0.120

For the base shear predictions, it was observed that ATC method yielded very close results with respect to MULTI approach in the elastic range. Unlike ATC, FEMA and 75%V_y over-estimated the force demand in this range in an error margin of 15%. As it was expected, after the yield of the systems, all methods yielded similar close results in terms of maximum base shear.

The overall evaluations with respect to MULTI approach showed that the order of mean prediction errors remained lowest for ATC, but all methods generally provided reasonable results in terms of displacement, drift and force demands. Therefore, bi-linear models of pushover curves can likely be used for simplified analyses without the need for introducing complex models of capacity curves.